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CHLOROFORM:

ITS

ACTION AND ADMINISTRATION.

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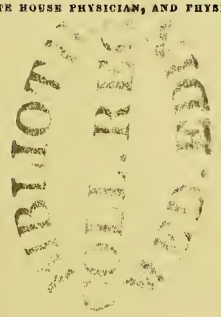
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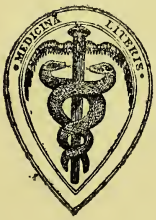
A HANDBOOK.

BY

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TO

DR. ARTHUR FARRE, F.R.S.,

THE AUTHOR'S TEACHER AND FRIEND,

This Book is Dedicated

WITH AFFECTIONATE RESPECT.

PREFACE.

I HAVE endeavoured in the following pages to present a brief résumé of our present knowledge concerning chloroform and its effects. The subject is so important that it cannot need apology; the apology must be for the Author.

My medical education commenced at a time when the vastness of the boon conferred by the discovery of the anæsthetic was just beginning to assert itself, and I was associated frequently with the late Dr. Snow, whose name is everywhere known in connection with the subject. For a considerable time also I was in the habit of administering chloroform at King's College Hospital, as well as in the practice of Mr. Fergusson and other friends (to whom I am anxious to express my obligations). Hence I have felt a real and practical interest in the matter of which this book treats.

I can scarcely avoid the hackneyed expression of "endeavouring to supply a want." It has appeared to me that the time has come when the separate experience and teaching of individuals may be advantageously formed into a continuous chain. I am well aware that I have imperfectly performed the task which I have undertaken, but I have strenuously endeavoured to combine the characteristics of truth and brevity.

A writer on chloroform cannot commence a list of those to whose researches he is indebted for his subject-matter without paying a tribute to the illustrious man who discovered the

properties of the anæsthetic. It seems to me that Dr. Simpson has never received a sufficient meed of thanks. If all those whose sufferings have been abolished by the agent he introduced were to join in the work, a noble monument might be erected to his fame. Why should not this be done?

I have been largely indebted to the classical work of the late Dr. Snow, to the researches of MM. Lallemand, Perrin, and Duroy, to Dr. Anstie's book on 'Stimulants and Narcotics,' and to the Report of the Committee on Chloroform appointed by the Royal Medical and Chirurgical Society.

I cannot sufficiently express my obligations to many kind friends—to Dr. E. Symes Thompson, for his most valuable assistance, to Dr. John Harley, of King's College, for co-operating with me in my experiments, to Dr. George Harley, of University College, for help in the consideration of the physiological question, to Mr. W. Spencer Watson and Mr. Harry Lobb, for assistance in the chapter on Resuscitation, to Dr. Alfred Meadows, Mr. Francis Mason, and Mr. Parkinson, for hints and advice in the obstetrical, surgical, and dental portions of the subject.

I hope that this little book may prove of some practical use, and that those whose critical eye may detect its faults will at least give me credit for having expended much labour in its compilation.

A. ERNEST SANSOM.

29, Duncan Terrace, N.;
May, 1865.

CHLOROFORM:

ITS

ACTION AND ADMINISTRATION.

CHAPTER I.

THE DISCOVERY OF CHLOROFORM.

Discoveries generally have long histories. They may startle with their apparent suddenness; but in reality they are the results of ages of patient toil, of efforts often misdirected, of lessons imperfectly taught, of experiences insufficiently recorded. Truths have been built up of the crumbling dust of errors.

Most of the great discoveries which have been of benefit to the human race have passed through an infancy which has been obscure, before attaining their perfect strength. The law of gravitation was taught, not by the fall of an apple, but by facts distributed throughout long ages. So also with regard to the discovery of the circulation of the blood. Erasistratus taught that the arteries of the body were filled with air. Galen, going a step farther, proved that they contained blood and not air, but Galen invested his thought with many errors. Step by step Servetus, Vesalius, Realdo Columbus, Cæsalpinus, and Fabricius, attained to a more complete knowledge. Errors were thrown aside as little truths were elicited, until at last there was built up in Harvey's mind the great fact of the circulation.

When Galvani experimented upon a frog placed upon a metallic plate there was probably the first step to the discovery of the electric telegraph. How gradually through

Volta and the host of observers which followed the first idea became developed into a science, and the science begat the practical result, is sufficiently known.

A process similarly gradual was observed in the case of the discovery of means for producing insensibility to pain, and of preventing the suffering which surgical operations inflict. The general idea was implanted at the earliest ages and was gradually developed; old systems were discarded as other and better ones presented themselves—and there was a culmination in the discovery of chloroform. None the less honour to him in whose mind this result was attained.

The ancients knew that, in certain states of the system, sensibility was wholly or partially destroyed; their observations upon epilepsy, catalepsy, upon advanced intoxication and the effect of certain medicinal substances, taught them this. They were acquainted with the power of medicines to relieve pain or assuage grief. Thus Helen tempers with drugs the draught that she offers to Menelaus and his friend.

> "To clear the cloudy front of wrinkled care,
> And dry the tearful sluices of despair,
> Charmed with that virtuous draught, the exalted mind
> All sense of woe delivers to the wind."*

These agents—Nepenthes—did not annul the faculty of sensation, but they deadened it.

The ancient Egyptians used many drugs for producing a state of intoxication or ecstasy; they were taken either as potions or electuaries. Of these there were various preparations of Indian hemp (Cannabis Indica), the juice of the poppy (Affion, the meconium of the Greeks) and another which was used when opium was scarce—the "electuarium bernavi."

The effects of these preparations of Indian Hemp are thus depicted.† First they cause exhilaration; the men who have swallowed them become talkative, sing love-songs, and laugh; then they are rendered delirious, and fight and mutilate each other. This stage lasts an hour, then follows a stage of wild excitement, the characteristic of which is violent anger. Lastly is a stage of grief, during which they weep and lament; then they return to normal health. Such was the enjoyment of the Egyptians in their "convivial feasts."

* 'Odyssey,' iv, 220.

† See 'Prosper Alpinus de Medicinâ Ægyptiorum,' lib. iv, c. ii.

Prosper Alpinus gives the formula of another electuary. It was composed of white poppies, the seeds of henbane, opium, the stem and flowers of euphorbia and saffron. These were mingled together with honey, and kept for six months. The effects may be imagined from the nature of the ingredients.

At the time of the Roman empire we find that means were employed for mitigating the pain of surgical operations. These operations were usually either incisions of the skin or actual burnings of the surface, no removal of parts of the body except such as were mortified being attempted. But even at this period we hear of methods of rendering the pain less intolerable. These were partly topical, partly general. Pliny relates how that a kind of marble obtained from Memphis was powdered, mixed with vinegar, and spread upon the parts to be cut or cauterized. The local action of the vinegar, the liberated carbonic acid, and the long-continued soaking of the parts, probably all contributed to produce the benumbing effect; and this, perhaps, was partly imaginary.

Other medicaments for the relief or prevention of pain were administered by the stomach. Both Pliny and Dioscorides describe these. The most important medicine was an infusion or wine made of the root and leaves of mandragora, one of the Solanaceæ,—"bibitur ante sectiones punctionesque ne sentiantur"*—"ante sectiones ustionesve."† Here, then, was a foreshadowing of the end—these potions were so administered as to cause a deep sleep, and during its continuance, whilst the patient was incapable of feeling pain, the operations were performed.

In another part of the world, means were employed to the same purpose. The Chinese surgeons of the third century were accustomed to use Indian hemp for the purpose of inducing insensibility, to relieve existing pain, and to annul the horrors of an operation. There is no doubt that the medicine was usually administered by the stomach; but in one account of its operation it is said that its effect was manifest at the *end of some instants*,‡ and therefore it is probable that it was ignited and the fumes inhaled.

Inhalation of narcotic vapours was practised at a very early age. The ancient Scythians used to breathe the fumes of burning hemp, just as the Hindoos do now—just as the Chinese

* Pliny, 'Nat. Hist.,' lib. xxv—xciv.
† Dioscorides, lib. iv, cap. 76.
‡ 'Comptes Rendus,' 1849, t. xxviii, p. 195.

smoke opium. The lethargy, the unreality which it brought about might very readily have suggested to the Chinese surgeon its use in preventing pain. The custom of inhalation, too, was very widely spread—among the barbarians of the shores of the Caspian, who lit fires of fruits and seeds, and sat round breathing the fumes till they became intoxicated; among the Indian tribes, who threw tobacco on their fires during religious ceremonies to transport them into a state of ecstasy; among the civilised nations, for the priestesses at Delphi became half intoxicated by the fumes of narcotic plants before delivering the oracles.

In a book upon Egyptian medicine which I have before quoted, there is a description of a method of applying the actual cautery. It is characterised as a humane method, and it seems probable that by the process employed, mitigation of the pain arose from the fact of the fumes of some of the agents being inhaled by the patient. If so, it is the first registered idea of surgical anæsthesia. Prosper Alpinus, in discussing the method, gives the Egyptians credit for using burning cotton or flax (Indian hemp?) instead of the hot iron. The plan was beneficial in two ways; first, the heat was thus applied gradually; and secondly, a kind of stupor was induced. It is possible certainly that the term *stupor* may mean only local insensibility; but from the fact of the virtues of Indian hemp being commonly known among the Egyptians, it is not unreasonable to think that it might have been taken advantage of. So, probably the substance which was used to produce the necessary heat, by its narcotic properties, relieved the pain. "Hence the sick more readily permitted this plan of treatment, nor did they dread that excess of pain which cauterizations with hot iron were apt to produce."*

* The following quotation relates to the method of employing the cautery:—

"Sensim ac sensim partem à succenso involucro extremo ad calorem disponi, atque ita calefieri ut toto involucro cremato, igneque ad cutem deducto cutis prius calfacta, fereque stuporem ex eo adepta, ignis incendium non omnino totum sentiat, neque ab eo admodum doleat, quod etiam ignis incendium rarioris involucri substantiæ ratione, neque immodicum sit. Duo igitur ex hujus præsidii operatione scitu digna animadvertuntur, quippe partem ab igne clementius inuri, atque ab ea haud immoderatum, qualis ex igniti ferri ustione sentitur, percipi dolorem, primum ab accensæ atque ignitæ raræ substantiæ, scilicet gossypii et lini ratione fit, atque secundum, præaccepto calore ex totius involucri combustione, quæ sensim

Long after the classic period, ages passed with no progress. The horrors of surgery were increased, limbs were amputated with red-hot knives, and potential cauteries were in the ascendant; yet little was done for the relief of the pain of these frightful proceedings.

In the twelfth century a Tuscan described how that suffering might be alleviated by the patient being allowed to inhale a narcotic vapour. This was the famous confection of Hugo di Lucca. It was composed of opium, henbane, mandragora, hemlock, &c. These, mingled with various juices, were taken up by a sponge which had been exposed to a very hot sun. As often as it was wanted the sponge was soaked for an hour in very hot water, and then held to the patient's nostrils—"quousque somnium capiat." Concerning the length of time required to induce that state of sleep, history is silent.

Albertus Magnus (thirteenth century) probably knew something of the use of ether as an anæsthetic. He gives a recipe for its preparation.*

In the sixteenth century mention is made of a soporific medicine by Porta, of Naples. The quintessence of certain drugs is extracted by somniferous menstrua, and is put in leaden vessels perfectly closed. When the vessel is opened and applied to the nostrils, a profound sleep is induced. Dr. Snow thought that the somniferous menstruum might have been sulphuric ether. In 1681 Denis Papin published a 'Traité des Operations sans douleur.' Little, however, came of it, and no progress was made towards the attainment of the end until the close of the last century. An impetus had been given to the study of the gases. Humphrey Davy found that inhalation of nitrous oxide mitigated the pain of cutting a wisdom tooth, and he threw out the hint that, "as it appeared capable of destroying physical pain, so it might probably be used with advantage during surgical operations."

At this same time the vapour of ether was used in the treatment of diseases of the chest by Pearson and Thornton; and in Nysten's Dictionary, published in France in 1815, an apparatus for the administration of ether vapour is figured. No general anæsthetic effect, however, was either attempted or thought of. Some ideas of the possibility of this may have

ac sensim procedit, cute calorem stuporemque adepta, non ita acute sentiente."—'Prosper Alpinus,' lib. iii, c. xii. Ed. Venet: 1591.

* See Smiles' 'Industrial Biog.,' p. 174.

crossed the minds of a few a little later, for in 1831 a case is recorded of a druggist who was found in a state of complete insensibility from having inhaled air strongly impregnated with the vapour of ether.

At this time chemists had pointed out the great resemblance between the effects of ether vapour and of nitrous oxide gas. Chloroform had just (1835) been investigated chemically by Dumas. Soon afterwards it was thus mentioned in Wood and Bache's 'American Dispensatory:'*—"In affections characterised by difficult respiration, chloroform may be used by inhalation."

Humphrey Davy's suggestion was not acted upon until 1844, when Horace Wells, the American dentist, used nitrous oxide successfully in several cases, inaugurating "a new era in tooth-pulling." Unfortunately he failed in one instance, owing to an accident—people could not reconcile the breathing of laughing-gas with the serious business of having a tooth extracted, so Wells was laughed out of his practice; but the idea sank deeply into the mind of Morton, Wells' pupil, who had heard of the employment of ether. Dr. Jackson, the chemist, was also impressed by it, and between them the value of ether was made known.

The history is here unfortunately sullied by a squabble. Was the merit of finding out ether as an anæsthetic due to Morton, the dentist, or to Jackson, the chemist? Many English books have given the credit to Morton; the last French book (Lallemand, Perrin, and Duroy) declares that Jackson made the discovery and communicated it to Morton. These discrepancies are reconcileable—the chemist selected the agent, reasoned by analogy on its probable properties, and gave it to Morton to put to a practical test. The experiment succeeded; neither could predict the result, but both should have the credit of it. However this may be, a man named Frost had a tooth extracted under the influence of sulphuric ether, absolutely without his knowledge of the operation, at 19, Tennants Row, Boston, on the 13th of September, 1846.

Thus, after long incubation, one of the greatest benefits mankind ever received saw the light.

The boon was too great not to be recognised. The news was brought to England, and ether was immediately employed

* Kidd, 'On Ether, &c.,' p. 54.

for surgical operations by Mr. Liston and Mr. Fergusson. No greater impression was ever made by any discovery. When Mr. Fergusson's first edition of his work on 'Surgery' was published, the great truth was unknown; in his second edition there are words forcibly indicative of the deep impression the discovery had made. He says:

"Since the last edition of this work was published, a vast and important change has come over the department of operative surgery. The discovery of anæsthesia or the means of causing insensibility to pain during the performance of operations has been made in the interval, and now instead of wild outcries or stifled screams and groans coming from the patient under the surgeon's instruments, he may be made to lie as quietly as if in a calm sleep, or possibly during the most painful applications of the knife under other circumstances, he may be mentally engaged in the most pleasing associations of thought, or singing, or humming by snatches some favorite air. It is, perhaps, not saying too much when this discovery is characterised as the greatest, in most respects, which has been made in the province of surgery."

In the early part of 1847 Mr. Jacob Bell used instead of sulphuric ether, chloric ether. This is merely a solution of chloroform in spirits of wine. It was successful in some cases; it came to be employed in some of the hospitals, and by Mr. Lawrence. It was, however, variable in strength, and its effects were not constant—moreover, it was expensive, so it fell into disuse. So near an approach did not suggest the employment of its active ingredient—chloroform.

It is strange that the compounds of formyle should have been used for their narcotic and sedative properties by unlettered peasantry. I have heard of crushed ants having been employed to allay local pain; and my friend Dr. Symes Thompson has communicated to me some interesting facts concerning their internal administration. In Norway, in the neighbourhood of North Cape, the common beverage of the lower classes was, in former years, a spirit (distilled, I believe, from parsnips) in which a bag of large white ants were boiled and left to simmer. When the ant-bag had remained for an hour or more in the spirit, it was removed; the intoxicating beverage was then served out. The effect of this drink was rapidly to produce a delightful dreamy condition, which soon passed into complete unconsciousness from which it was impossible to

rouse the tippler by loud speaking, by shaking, or pinching. The state of unconsciousness would, however, in the course of an hour or two pass away, leaving the individual perfectly well and clear-headed, without any headache or other discomfort, and with no remembrance of anything except a pleasing dream. So complete was the anæsthesia produced, that surgeons were accustomed to perform operations upon those whose sensibility to pain had been in this way removed. The facts, however, did not suggest any further investigation in this quarter.

In March, 1847, Flourens announced to the Academy of Sciences of Paris certain observations on the anæsthetic powers of chloroform upon animals. He considered it dangerous. Meanwhile, Dr. Simpson, of Edinburgh, had experimented on many hydro-carbons, on acetone, nitrous ether, &c., with a view of determining their anæsthetic properties. On the memorable evening of November 4th, 1847, he determined on trying a hitherto discarded, heavy fluid, CHLOROFORM.

Dr. Miller gives a graphic account of this birth of chloroform. Doctors Simpson, Keith, and Duncan sate each with a tumbler in hand, and in the tumbler a napkin. Chloroform was poured upon each napkin, and all patiently inhaled and waited for something to turn up. After a probation, Dr. Simpson, drowsy as he was, became convinced that something *had* turned up, for he heard Dr. Duncan snoring, and Dr. Keith kicking about in an inelegant manner. All these effects had been manifest in a very short time, and the experimenters (or experimentees) all agreed that chloroform was far more agreeable than ether.

Hereby, then, Dr. Simpson established an agent far quicker in operation, far more pleasant than ether. Soon afterwards, chloroform was administered to a highland boy, and a diseased portion of the bone of his forearm was removed absolutely without pain.

CHAPTER II.

THE INFLUENCE OF THE DISCOVERY.

The use of chloroform in surgical operations soon became general. Abolition of pain was produced by it so much more readily and speedily than by ether; moreover, the quantities which were required were so much smaller that this latter gave place to it. Chloroform, however, had not been employed more than three months when a death occurred which was attributed to it: and very soon other deaths followed. People then began to look their gift horse in the mouth, and urged a most proper investigation as to the value or the danger of it. A very slight acquaintance proved it to be a most powerful agent—for evil as well as for good. It was found that its tendency, if insufficiently diluted with air, was invariably to cause death; and, therefore, that a sufficient dilution of the vapour was a *sine quâ non*. Ether, as compared with it, was much less powerful, and had never been known to exert a fatal influence. A further acquaintance, however, showed that in the case of ether there was far from an immunity from danger, and the large quantities requisite to produce insensibility rendered it of less easy application. M. Trousseau collected details of forty-nine cases of death from the use of these anæsthetics—thirty were from chloroform, and nineteen from ether.

Throughout the civilised world the use of chloroform spread. Dilutions of it with alcohol, or ether, were employed in Italy and Austria; but in America the use of ether was to the greatest extent persisted in. As the matter now stands, the use of chloroform is increasing; that of ether diminishing. Ether is inconvenient. More than a pint of it is sometimes requisite to produce and sustain the insensibility necessary for an operation, whereas a few drachms of chloroform suffice. Ether causes excitement and sensations of choking, and the large quantities which escape into the air in the tedious process of inducing anæsthesia become a nuisance to the operator and to all around. Moreover, frequently, from the large amount required, operations have been performed when there has been an insufficient affection of sensibility, and so the great

object, the abrogation of pain, has been unattained. The use of ether has never been so universal as the use of chloroform, and therefore the relative frequency of deaths is far from being the expression of the danger of the two agents respectively. The question seems to resolve itself into this: ether being weaker is *à priori* a less dangerous substance than chloroform; but chloroform vapour freely diluted with atmospheric air can be rendered as innocuous as ether vapour.

A most important thing is to establish something like an expression of the danger of chloroform. Throughout these pages I shall endeavour to inculcate a just estimate of this. A positive statement of it is impossible, so many considerations interpose; but I believe that the facts warrant the conclusion that the danger of chloroform has been exaggerated. Be that as it may, "litera scripta manet," a hundred and twenty-three deaths from chloroform have been recorded; and it is probable that the number attributed to it is nearly three hundred.

This assertion, startling at first sight, becomes less formidable after a close scrutiny. How many times has chloroform been employed?

Dr. John Chapman, in the 'Westminster Review' for January, 1859, made a rough computation of the rates of deaths to inhalations. Assuming that 3000 is the average number of operations that had been performed in each of the metropolitan hospitals in the foregoing ten years, and taking this as the basis of a calculation of the number performed in those countries wherein the practice of anæsthesia prevailed, he considered that at least 1,200,000 operations had been performed under chloroform. There were, when he wrote his paper, 74 recorded cases of death from the use of anæsthetic agents; the chances were, therefore, about 16,000 to one against a patient who consented to become anæsthetised losing his life by the direct agency of the means employed.

During the Crimean war, chloroform was used almost universally in the French and English camp. Baudens says* that no accident occurred throughout the French-Eastern campaign, though it was used 30,000 times or more. In the Crimea alone it was administered more than 20,000 times, according to M. Scrive. The English ranks were not quite so fortunate—one case was fatal under the use of impure chloro-

* 'Rev. des deux Mondes,' Ap., 1857.

form, and there was one death from shock, probably accelerated by chloroform. I can find in the Blue Book of the campaign no approximative statement of the number of times chloroform was employed, but it is fair to suppose that a large proportion of the wounded received into military hospitals required it either for the exploration of bullets, or for the performance of operations, and 12,094 officers and men were treated in military hospitals.

During the French-Italian war, chloroform was used as extensively as in the Crimea. Surgeon-Major Armand says that he never heard of an accident from its use.

It has been estimated that chloroform has been employed in midwifery practice 40,000 times in London alone, and there has not been here a single accident from its use.*

In the course of the publication of the admirable papers by Dr. Richardson on the Medical History of England, he remarks :† "It is interesting to note that in the course of these papers this is the first case in which chloroform has been reported as causing death in hospital. It may be well, therefore, to sum up the number of administrations which have been recorded."

In Norwich hospital	2,250
Lynn hospital	900
Stafford hospital	750
Wolverhampton hospital	4,000
Newcastle-under-Lyne hospital . .	3,000
Brighton hospital	1,200
Birmingham hospital (General) . .	2,800
„ „ (Queen's) . .	2,100
Total .	17,000
Death, 1.	

In this statement the lowest possible estimate of the number of administrations is entered.

When we consider all these circumstances—when, moreover, we think of the vastly increasing use of chloroform in surgery, we cannot think that even three hundred deaths present a very large mortality ; still less when we further analyse facts and conclude, as we must, that some of these set

* Kidd, 'Dublin Quarterly Journal of Medical Science,' May, 1864, p. 323.

† 'Med. Times and Gazette,' Aug. 27th, 1864.

down as the fatal consequences of chloroform may have been really due to extrinsic causes.

It is a strange, and certainly a notable fact that a large proportion of the deaths occurred before the commencement of the operation for which anæsthesia was to be induced. Combining the results of Snow, Scoutteten, and Kidd, it appears that 44·6 per cent. occurred before the commencement of the operation, 34·7 per cent. during the performance thereof, and only 20·6 per cent. shortly after the completion. Now, in the first case, in which Dr. Simpson proposed to try the effects of chloroform in a surgical operation, a boy was to be cut for stone. Just as the preliminaries were arranged the boy died. Not a breath of chloroform had been given. If it had, the birth of the anæsthetic would have been its death. So in another case, an apparatus for administering chloroform was applied to a patient about to be operated on. Suddenly he died. All around thought chloroform had brought about the result. When they came to examine matters, they found that the valve was closed, and not a whiff of chloroform had entered the lungs. Is it not very reasonable to suppose that some such cases have swelled the ranks of the supposed deaths from chloroform? Is it not likely that some were rather deaths from fright, or shock, or apprehension? Such were not wanting before chloroform was thought of. It is told of Desault, that just as he was once about to perform lithotomy, he traced with his finger a line on the skin of the patient—the man shrieked and fell dead. A similar result occurred when Chopart was about to perform a simple operation. Another occurred in the practice of Mr. Stanley.*

I think, therefore, that the apparent mortality is not an accurate expression of the danger of the anæsthetic. I shall hereafter express my opinion that the mortality is to a great extent preventible.

The existence of a large number of cases, however, wherein chloroform has evidently by its own operation induced symptoms of death or danger, not less than our own daily experience of its marvellous power, teaches us that we have to deal with an agent of no fancied danger; and when we meet objectors to its use, we are to answer them with plain facts and calm reasoning, not to "pooh-pooh" them out of their fears.

* See Kidd, 'Med. Times,' Aug. 18th, 1860.

A class of objections of a different kind has been raised to chloroform, on the ground that by its power over the system it superinduces such a state as to render recovery from operations less probable or less felicitous; that, in fact, since its use the mortality after operations has increased. We generally find a patient much more calm and comfortable when chloroform has been administered, than when he has endured the agonies of pain. Is this benefit visionary, and does the anæsthetic predispose to a fatality?

Dr. James Arnott, in 1856, brought forward certain statistics which seemed to show that chloroform *had* increased the danger of operations. Dr. Arnott's opinions were shared in by Dr. Gordon, in a report read before the Crimean Medical Society, and by Dr. Mouat; but they were negatived by a number of other observers. Without waste of words, I append a table of data:—

Mortality per cent. after Amputation.

	Simpson.	Snow.	Arnott.	Fenwick.	Sansom.	Malgaigne and Trélat.	Guthrie and Records of Crimean War.
Before anæsthesia	29	...	20	24	36·78	54·8	44
After „	23	27	34	24	33·	45	27·3

Can anything better show the fallacy of figures in a case of this sort? So many considerations interpose, that a *post hoc* cannot become a *propter hoc* argument. Thus we see that the rate of mortality that Dr. Arnott has fixed upon as his standard before the introduction of anæsthetics is far more than doubled in the records of French practice of both periods. I have introduced this table not for the purpose of showing facts, but for disclosing discrepancies. These statistics cannot be other than a chaos of inequalities.

Proceeding by the method of elimination, we still see a great variation in results, as in the following table:—

Mortality per cent. after the several Amputations.

	Before Anæsthesia. — Guthrie.	After Anæsthesia. — Crimea.	Before Chloroform. — Malgaigne.	After Chloroform. — Trélat.	Before (1840) — Sansom.	After (1856) —
Arm, Forearm	34	...	45	42·5	23·8	21·4
Thigh	52	64	62·6	52·7	40·7	28·3
Leg		30·3	55·2	44	41	33·3

The general teaching here seems to be that chloroform has *decreased* the danger of amputation; at any rate that it has not increased the mortality. The Chloroform Committee of the Royal Medical and Chirurgical Society have thus summed up their investigations on this subject:—"The results of 2586 capital operations performed before, and of 1860 performed since, the introduction of anæsthetics, collected from all authentic available sources, prove that anæsthetics have in no degree increased the rate of mortality.*

Far more potent influences on the rate of mortality after operations are the ventilation of hospitals, the careful treatment of patients, the promotion of sanitary measures. Mortality was at its highest in France when the treatment was so applied as to excite as much suppuration as possible, and when the wards were most crowded.

It is not profitless to pursue the method of elimination in this mass of facts still further. When the cases are considered with reference to the cause for which amputation is required, the results are well worthy of notice. From much investigation I have been led to these conclusions.† In cases of amputation rendered necessary by a severe injury, there does not seem to be any improvement in the rate of mortality of late years. In case of operations for disease there has been

* 'Proceedings of Royal Medical and Chirurgical Society,' 1864.

† See Essay by the author 'On the Mortality after Amputations.' London: Churchill, 1859.

a marked improvement. I extract a table which shows the mortality per cent. after amputations for diseases of bones and joints.

	All members.	Thigh.	Leg.	Upper Extremities.
Pre-chloroform period —				
1837—1842 . . .	33	29	44	23
1840	34	43	25	40
Post-chloroform period—				
Jan., 1856, to July, 1857	19	20	17	14
1854 and 1855 . .	20	20	23	8

To proceed to a slight analysis of these deductions. In severe accidents necessitating an immediate operation, I believe that we should hesitate before administering chloroform. We shall see farther on that the primary effect of chloroform is less favorable in the case of strong, robust men, than in patients of a feebler organization. An accident happens to a hale man in the full enjoyment of life—he has to bear first the shock of the injury, then the shock of the operation, and (if so intended) the further impression of a powerful anæsthetic. His system is less able to withstand this accumulation of influences than the system of one whose powers of life have, as it were, gradually submitted themselves to the dominion of disease. And, as I have elsewhere observed, "the humanity which would urge the sparing of suffering, might regret but little the withholding of the anæsthetic agent here; for the sudden shock to the nervous system has already to some extent blunted the sensibilities and rendered less poignant impressions of pain."

In cases of disease in which amputations have been performed, I believe there can be no doubt that the results have been more favorable since the introduction of anæsthesia. Two causes combine to produce this result. In the first place, persons now more readily submit to operations, the lives are not so diseased when operations are performed as formerly. The beneficent influence of chloroform allows of surgical interference at a more hopeful time. But principally, the terrors and pain of surgery being abolished, the subsequent depression

is lessened and recovery is promoted. The manipulation of the surgeon upon the structure is better borne at the time when the sense of pain is annulled. The handling of certain tissues—tendinous ones especially—will in sensitive patients frequently induce alarming syncope. Claude Bernard* found that if animals were etherised their medulla oblongata could be *destroyed* without causing death; but if unetherised, a *mere pricking* of the medulla would induce instant death from cessation of the heart's action.

I have thus been led in the consideration of the subject to the immediate causes of death after operations. They are (1) Shock or Exhaustion. (2) Pyæmia—morbific change in the blood.

I have said that, in amputations for injuries, when these amputations are done during the time that the injury is producing a primary influence on an otherwise healthy organism, chloroform probably does mischief. In other cases, when the primary shock has passed off, this does not obtain. Dr. Fenwick considers that, since the introduction of anæsthesia, the danger of shock is altogether lost in the case of operations for disease.

As to pyæmia, there is little doubt of its decrease during late years, though this is probably due more to the inculcation of hygienic measures than to any influence chloroform may have had. Dr. Arnott, in his objections to anæsthesia, stated that pyæmia had probably been rendered more prevalent and fatal. He is answered by Mr. Holmes, who shows that it equally prevailed with those suffering from compound fracture who had had no chloroform; moreover, pyæmia had been more prevalent during the three years in which Dr. Arnott's statistics of amputations had been collected, than in the five years in which chloroform had been used.

The influence of anæsthesia on the progress of Surgery has been wonderful. Operations are now performed for the removal of diseased bone, whereas in times past the limb would have been sacrificed or the timid patient left unrelieved. Diseased portions of joints are removed, and the patient left with a good limb; whereas before, he could only have had a stump. Operations have grown out of the practice of anæsthesia—witness the removal of ovarian tumours from women, who in

* 'Système Nerveux,' vol. i, p. 284.

times past had to succumb to a sure and speedy death. In how many other instances has life been rendered worth living for!

From all the considerations I have advanced, I think the following conclusions may be drawn:—That though chloroform has in many instances caused death, it has not the fatal power which might at first sight appear. That, excluding the various chances which all chloroformed and not chloroformed must submit to, by utilising our increased knowledge and exercising an increased care, we may deprive it of nearly all its terrors. That by the immense preponderance of its influence for good, it has been a direct conservator of human life.

CHAPTER III.

THE CHEMISTRY OF CHLOROFORM.

Chloroform is a colourless liquid, having an aromatic and penetrating smell. Its taste is sweet, and it produces a sense of warmth by its caustic action upon the tongue. It is about one and a half times as heavy as water, but a drop of it is of so small a volume that, strange as it may seem, it has only half the weight of a drop of water. Its specific gravity is 1·48—·49. It is a solvent of fats and oils, of a large number of the alkaloids, of india-rubber and gutta-percha, and of resins, but has a very slight solvent action upon sulphur and phosphorus. It readily dissolves iodine, forming a beautiful deep violet solution. It is miscible with alcohol and sulphuric ether in all proportions.

The gradual discovery of the various properties of chloroform affords one of many instances of the value of careful study as preliminary to generalisation. It is a complete argument against the "cui bono" cavil of those who inveigh against philosophical inquiries. The liquid Chloroform, the product of the action of hypochlorite of lime upon alcohol,

discovered by Soubeiran, was a chemical curiosity, nothing more. It was then called bichloric acid. A little was added to its chemical history by Liebig, who obtained it by the action of alkalis upon chloral; but Dumas, in 1835, demonstrated its true character. He established its chemical formula as C_2HCl_3, and he gave it the name it bears. Twelve years it remained upon the laboratory shelf, till Flourens tried its physiological action upon animals; and shortly afterwards Dr. Simpson employed it, after having tried the other hydrocarbons. Further investigations upon chloroform have shown that it is produced under any of the following circumstances:

1. When a hypochlorite is distilled with alcohol, wood spirit or acetone.
2. When chlorine acts on proto-carburetted hydrogen, or on hydrochlorate of methylene.
3. In the reaction between the alkaline hydrates and chloro-acetic acid, or the chlor-acetates.
4. In the distillation of hydrated chloral with baryta-water or lime-water.
5. By the action of marsh gas on carbonic acid with an excess of chlorine.

Chloroform of a density of 1·49 has this property—if alcohol be added to it to any extent up to five per cent. it is rendered opaline; if the proportion be augmented to ten per cent. its limpidity returns. It boils at a temperature of 140° Fahr.

When the vapour of chloroform is passed through a porcelain tube heated to redness, carbon is deposited, and there are produced hydrochloric acid, chlorine, and an inflammable gas; certain long white crystals are also deposited, which seem to be a chloride of carbon (C_4Cl_2). If instead of the pure vapour of chloroform being thus employed, the same is mixed with atmospheric air, no carbon is deposited, but the gaseous products are hydrochloric acid, chlorine, carbonic acid, and some volatile chlorine compounds.

If the vapour be passed over copper or iron heated to redness, the products are a metallic chloride and carbon.

The MANUFACTURE of chloroform is conducted according to the method of Soubeiran, modified by Huraut Moutillard, and Larocque. Its essential point is the distillation of rectified spirit with water and chloride of lime; but the addition of quick-lime renders the product more abundant and more pure.

The following is the process observed in an extensive chemical manufactory:*

Chloride of lime (CaOCl) 130 pounds, and seven pounds of ordinary lime are formed into a paste with water, and placed in a large earthenware alembic. After stirring for some time, more water and twenty-five pounds of rectified spirit are added; care being taken that the still is not more than half full, the head is well luted, and a gentle steam heat applied. An impure chloroform distils over, accompanied by a lighter fluid; the former is separated by decantation, and the latter is returned to the alembic together with some of the primary ingredients. After several repetitions of this process, the resulting chloroform, still impure, is poured into an ordinary still with five times its weight of distilled water, and with a little quick-lime. The heat of a water bath is applied, and the resulting product, which consists of water and chloroform, is collected.

For further PURIFICATION the chloroform should be thoroughly washed with water, then shaken with a solution of carbonate of soda to remove any free chlorine; finally, the chloroform, being separated, should be redistilled with a little dry chloride of calcium.

On a less extensive scale, chloroform may be prepared in this manner:†—Chlorinated lime, 10 pounds; rectified spirit, 30 fl. oz.; water, 3 gallons, chloride of calcium, 2 ounces slaked lime, q.s.; sulphuric acid, q.s.; distilled water, 9 fl. oz. The rectified spirit and water are distilled with a mixture of slaked and chlorinated lime, the distillate well agitated with water, and the lower stratum, which is crude chloroform, separated, repeatedly washed with water and well shaken with its own volume of sulphuric acid; the layer of chloroform is again separated, mixed with chloride of calcium and slaked lime, and purified by redistillation.

The great importance of having a perfectly pure chloroform cannot be overrated. Sometimes that supplied for the purpose of anæsthesia is impure. In several cases in which death has resulted, a subsequent examination has detected a considerable impurity. Witness the case which occurred during the Crimean war; a second case recorded in the 'American Journal of Medical Sciences,' for July, 1858; a third related by

* Muspratt's 'Chemistry,' p. 471.

† Garrod, 'Essentials of Materia Medica,' 1864, p. 135.

Dr. Burge, of New York (see 'Med. Times,' 1858, vol. i, p. 416). I have myself had chloroform given me for use in hospital, when, on attempting to administer it, unusual coughing has been provoked. On pouring it upon the hands, the smell of chlorine has been detected.

The ADULTERATIONS and IMPURITIES of chloroform may be divided into three classes—I. Those, such as alcohol or ether, which reduce its strength. II. Those methyl-compounds which result from methylated, instead of rectified spirit being employed in the manufacture. III. The products of decomposition.

I. The first test of the presence of this class of adulterations is a low *specific gravity*. The sp. gr. of chloroform should never be less than 1·48.

A small fragment of *sodium* thrown into chloroform should remain unchanged; if an impurity be present, there ensue decomposition and evolution of gas.*

ALCOHOL is detected by adding a crystal or two of chromic acid, or a little bichromate of potash and sulphuric acid; its presence is shown by the production of the green oxide of chromium. I consider the following the best mode of applying this test. Make a solution of two grains of bichromate of potash in one ounce of strong sulphuric acid. Put a little of this test liquid in a test-tube, and add an equal quantity of the suspected chloroform. Shake for a moment; if the proportion of alcohol be considerable, the change in colour from yellow to green is instantaneous; if only a very small quantity is present, the change is not seen till after the lapse of several minutes. This test is very delicate; it will detect two and a half grains of alcohol to the ounce.

Letheby's test for the presence of alcohol consists merely of the addition of a drop or two of the suspected chloroform to white of egg. If alcohol is present, the albumen is coagulated; if the chloroform is pure, no change results. This test I have found detect a proportion of alcohol equal to between 2 and 3 per cent. Three per cent. is readily detected.

Mialhe's test is of very ready application, and is of sufficient delicacy for most practical purposes. The chloroform is dropped into distilled water. If pure, the globules of chloroform which sink to the bottom preserve their perfect transpa-

* Observation of the boiling point is also a good test of the purity of a given specimen.

rency. If alcohol be present, they possess a milky appearance.

Most of the chloroform employed in America is diluted with alcohol. Frequently the specific gravity of American chloroform is as low as 1·45, which would indicate a proportion of alcohol above 5 per cent. according to M. Besnou.

ETHER is detected by the tests for alcohol. It may be recognised by its smell. Moreover, if chloroform containing ether be added to an aqueous solution of iodine, the globule which sinks becomes coloured a dull red. If the chloroform be pure, the drop is perfectly translucent, and of a violet or amethyst colour. (Berchon).

II. The compounds of methyl are among the most disagreeable and probably dangerous contaminations. They cause a suffocative feeling, nausea, throbbing headache, and prostration. The chloroform, made from methylated spirit, is much used for photographic purposes. It has been employed medicinally with a very false economy.*

Tests for methyl compounds.—Very strong sulphuric acid becomes black when mixed with chloroform containing them.

Dry chloride of zinc shaken with the suspected liquid precipitates a blackish, oily compound—a chloruretted oil.

Tests for impurities of first and second division.—A test for detecting spirits of wine, ether, aldehyde, methylic or amylic alcohol, has been established by M. Roussin. It consists in the addition of a little binitro-sulphide of iron to the suspected chloroform in a test-tube or stoppered bottle, and shaking them together. If there are any of these impurities, the chloroform acquires a brown tint.

The binitro-sulphide may be procured by mixing a solution of nitrite of potash with one of sulphide of ammonium, and adding, whilst the mixture is shaken, a solution of proto-sulphate of iron. After boiling and evaporation to dryness, the residue is treated with alcoholized ether, and left to crystallize.

III. The third division is the most important, because the chlorine products of the decomposition of chloroform constitute its gravest impurity.

Time, air, light—the last most potently—dispose a variety of changes in chloroform, the formation of certain hydro-chloro-

* Dr. Thudichum has found it decompose more readily than chloroform made from alcohol.

carbons, hydrochloric acid and free chlorine. All these are dangerous to be respired.

Chloride of elayle may be recognised by the addition of liquor potassæ, which developes the nauseous odour of chloride of acetyle. (Berthe.)

Hydrochloric acid may be discovered by its properties of reddening litmus and precipitating nitrate of silver. *Hypochlorous acid* also by its smell.

Free chlorine may generally be recognised by its odour or by its bleaching litmus.

It is better to shake the suspected chloroform with a little distilled water, and then add a solution of nitrate of silver; the white precipitate of chloride of silver indicates any of these chlorine impurities.

Vaporization of Chloroform.—The cardinal point which makes chloroform of such value for inhalation is its extreme volatility. It evaporates at all temperatures. Air at 40° Fahr. can retain 6 per cent. of chloroform-vapour, at 60,° 12 per cent. This is of great importance in regard to the administration of chloroform; it should be recollected that in hot weather or where the circumambient atmosphere is of a high temperature, double the proportion of chloroform may be administered of that in winter time or when the room is cold.

Evaporation being rapid, cold is produced in the process. Thus, chloroform administered upon a sponge has been known to cause freezing of minute drops of water on its surface. In order to ascertain to what degree the temperature might be, under ordinary circumstances, reduced, I drew currents of air through chloroform contained in a metallic cylinder (the internal portion of Snow's chloroform inhaler). The temperature sank ultimately to 33·5. This circumstance, the production of cold by the evaporation, renders the quantity taken up by the air more and more limited, so that a patient breathing chloroform from a free surface will not receive so large a proportion at the later stages as at the early stages of the inhalation. Dr. Snow preserved a constant temperature by surrounding the reservoir from which chloroform was inhaled with water. I have done so with gutta-percha. In either case the temperature does not sink below 38°.

Although this circumstance has been urged as a great difficulty to be met in the construction of instruments for the

* See a paper by the author in 'Lond. Med. Review.'

equable inhalation of chloroform, I do not think it of extreme practical importance. It is only after prolonged evaporation, after many inspirations of air over the chloroform-moistened surface, that a degree of cold is produced which seriously interferes with the production of the vapour.* I caused twenty-two cubic inches of air of a temperature of 47° to be drawn eighty times over a drachm of chloroform enclosed in the metallic cylinder, surrounded with water, of Snow's apparatus. The temperature sank to 40°. The same being done in case of the metallic cylinder without the interstratum of water, the temperature sank to 39·5° and 38·5°. Here was a difference of no practical moment. It was only by the introduction of another drachm of chloroform and the occurrence of eighty more insufflations that the differences were manifest, the temperature continuing at 38° in the case of the cylinder surrounded with water, and sinking to 35°, 34°, and 33·5° when not so surrounded. In actual practice, the occasional intermission of the insufflation gives time for the restoration of temperature. Furthermore, I found that there was no particular diminution of the proportion of chloroform inhaled. Twenty-two cubic inches of air being drawn over a drachm of chloroform thirty times, the proportion of vapour in the air inspired was 5·9 per cent. The operation being repeated, it was 5·3 per cent. Twenty measures being inspired, it was 5·6 per cent. As will presently be shown, it is of infinitely greater importance to obtain a reduction of this percentage by a sufficient commingling with air, than to provide for and maintain the rate of vaporisation. The fault is not of administering too weak a dose, but the contrary.

Detection of Chloroform.—The best mode of determining the presence of chloroform in solids or liquids is that of M. Duroy.* The apparatus consists of a tubulated retort (or a wide-mouthed receptacle) fitted with two tubes. The retort is attached to a porcelain tube which passes through a small charcoal furnace, and ends in a glass tube bent at a right angle, and dipping into a small bottle containing a solution of nitrate of silver in distilled water. Passing from this bottle is another small tube for the exit of air. Through the aperture of the retort a tube passes which is attached to a pair of bellows; so that the matters to be examined (if decomposing or ammoniacal they must first be acidulated with nitric acid), being put into

* 'Journal de Pharmacie et de Chimie,' Avril, 1851.

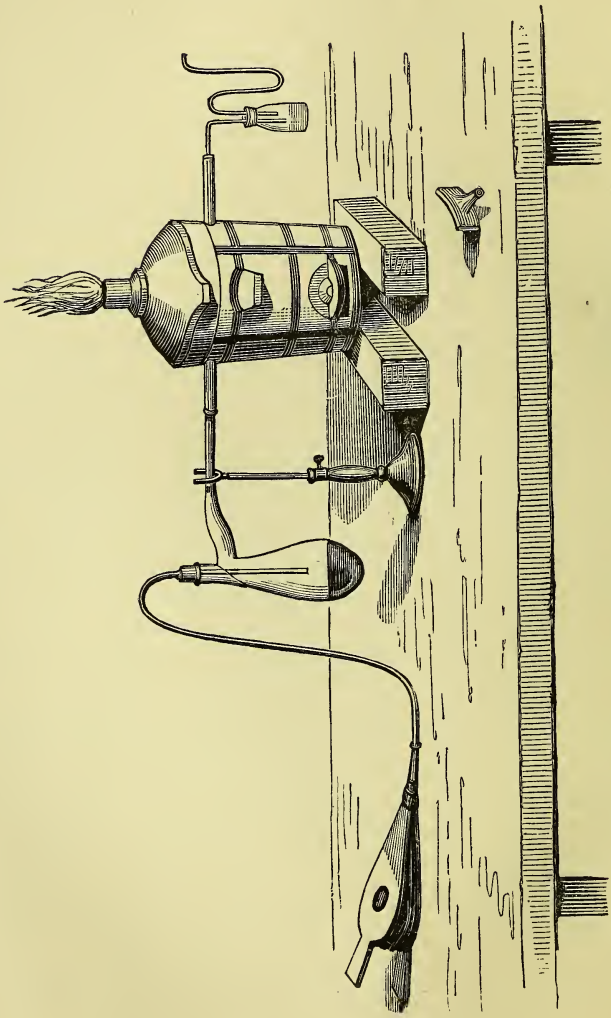


FIG. 1.

M. Duroy's apparatus for the detection of chloroform.

the retort, a current of air can be blown through them, and the chloroform vapour be carried along in the current. Arrived in the heated porcelain tube, the chloroform is decomposed; hydrochloric acid is liberated, and causes a white precipitate in the solution of nitrate of silver; chloride of carbon is deposited in crystals in the glass tube; carbonic acid and chlorine escape. The last can be detected by a piece of white paper moistened with a solution of iodide of potassium and with starch, the paper turning blue on account of the liberation of the iodine by means of the chlorine.

This process is said to be as delicate as Marsh's apparatus for the detection of arsenic.

By collecting the amount of hydrochloric acid and estimating it volumetrically by a solution of carbonate of soda, an approach to a quantitative determination of the chloroform is made.

By these means MM. Lallemand, Perrin, and Duroy have determined the relative properties of chloroform in the various portions of the system after death from chloroform; the blood being taken as the standard representing 1, the brain contained 3·92 parts; the liver, 2·08; the muscles, 0·16.

CHAPTER IV.

THE EFFECTS OF THE INHALATION OF CHLOROFORM.

The notions which are current concerning chloroform and its effects are in great degree strange and erroneous. Among the public there is much perplexity, many ideas based upon false reasoning, and much ignorance even with regard to the nature of the agent itself. Many people scarcely know whether it is solid or liquid: but, I think, the most widely spread error is that concerning the instantaneousness of its action. It is supposed to be only necessary to hold the chloroform over the patient's nose and mouth, and insensibility is produced. Its danger has been sometimes magnified, sometimes estimated

too lightly, but nearly always it is supposed to be specially hurtful in cases of disease of the heart. Considering the frequency of heart-affections, real or supposed, we cannot wonder at the frequently expressed alarm of our patients. This notion of connecting the relative danger of chloroform with states of disease of the heart will be shown to be the result of reasoning from insufficient data. It has done harm in alienating the confidence of patients from chloroform itself, and it has produced the impression in many cases that imperfect means have been adopted for ascertaining the state of the patient prior to the inhalation. So, frequently medical men have been blamed, because it is said the deaths have occurred in the subjects of a disease which has not been detected until the coroner's order has given the necessity of a search for it.

It will be well for all, doctors and patients, if a more correct appreciation of the nature and action of chloroform be arrived at. It is strange, not that there should be so much scepticism, but that there should be so little inquiry.

The vastness of the boon no doubt has been such that it has asserted itself above all the evidence of its danger. When, however, we feel convinced that these stumbling-blocks can be removed, and the benefit can shine with its own perfect light, it becomes us to try our utmost in the task.

Chloroform has usually been administered by being poured upon a towel, napkin, piece of lint, or piece of sponge, the vapour being rapidly given off at ordinary temperatures of the air. That this is essentially an unreliable and unsafe proceeding I shall presently show, but it will suffice us to presuppose this method for the present; for though in the twenty thousandth case it may prove fatal, in all the other instances no danger may occur.

When chloroform is thus breathed from a napkin, or handkerchief, the first symptoms are usually unpleasant, but these depend entirely on the strength of the vapour inhaled. Freely diluted, it is not unpleasant, but sweet. Strong, it is pungent, and causes a sensation of dryness. A breath of the insufficiently diluted vapour induces a gasp, and the patient is anxious to brush away with his hand the towel or napkin. When, however, plenty of air is mixed with the vapour, the patient breathes it calmly and quietly, and his sensations are pleasurable.

It is important to recollect that chloroform has a local, as

well as a general effect. Upon a sensitive surface it causes smarting and acts as a caustic. The fauces, the mucous membrane lining the throat, constitute an eminently sensitive surface, destined by nature as a guard against the entrance of deleterious matter into the lungs or the stomach. An irritation of the fauces or of the glottis causes a reflex effort to get rid of the irritant—vomiting or coughing is induced. Further, the effect causes spasm of the glottis. A strong dose of chloroform at first causes these signs of irritation, of expulsion, of spasm. Soon, however, the second effect of the narcotic becomes manifest, the sensibility of the surface being dulled by the local action of the chloroform, the spasm is controlled, and the irritation is no longer manifest. Then the state of irritation is exchanged for one of partial paralysis.

The following experiments were made by the Committee appointed by the Royal Medical and Chirurgical Society to inquire into the uses and the physiological, therapeutical, and toxical effects of Chloroform, as well as into the best mode of Administering it, and of obviating any ill consequences resulting from its administration.

When dilute chloroform vapour (5 per cent., or less) was blown upon the fauces, very little inconvenience ensued, and the animal continued to breathe in a natural manner.

If, however, air saturated with chloroform was employed, an instant and violent effort at deglutition was produced; with this effort the whole pharynx was seen to become contracted, the larynx advanced, and the epiglottis became hidden by the act of swallowing. This act was repeated many times (the use of the strong vapour being continued), but it gradually became less vigorous, and after about a minute it ceased, the animal by this time generally passing under the influence of the chloroform. The epiglottis then became fixed: it projected forwards, both during expiration and inspiration, and the vocal cords approximated at each expiration.

The following physiological conclusions are arrived at—

If concentrated chloroform vapour be suddenly administered by the mouth, a spasm of the fauces is induced, which lasts for some seconds; afterwards, when the animal has inspired, the phenomena of asphyxia are, for a time, associated with those of chloroform poisoning.

If partial insensibility be first induced by weaker chloroform, no spasm of the fauces ensues upon the sudden administration

of the concentrated form of the agent.—('Medico-Chirurgical Transactions,' vol. xlvii, p. 332.)

It is important, as I have said, to know that the popular notion of the instantaneousness of the production of insensibility by chloroform is a mistake. Four minutes are at the least required to produce insensibility; more to make it profound. I have never in any instance seen any helplessness whatever produced in less than from two to three minutes, and that with the full consent of the patient. We have heard stories of crimes being attempted whilst the victims have been close to a crowd of people, or in a railway carriage with other persons, and it has been said that chloroform has been employed by the perpetrators. This is very difficult of belief. Without the consent of the patient, or without his being forcibly held for at least several minutes, insensibility cannot be produced. It is possible that a crime might be committed at the instant that strong ammonia be held to the nose and mouth, so as to cause a temporary suffocation; but I do not think this possible in the case of chloroform.

No doubt chloroform has in some few instances aided crime, but this has been in cases wherein the victim has been unable to appeal from it, or when he has been so subdued, or so persuaded that he has inhaled it for three or four minutes.

To return. The first symptoms induced by chloroform, gradually administered, are those of exhilaration, such as those of a glass of wine. The pulse beats with an increased quickness, and, at first, with an increased force.* This may, just at the commencement, be influenced by alarm; but alarm is usually soon quieted. And it cannot be wholly so, for the rule is universal in the stoic as in the timid female; and in all animals under chloroform there is this increase in the rate of circulation. There is generally a bright expression of face; the tendency is usually to cheerfulness, and while unconsciousness is yet unaffected, there is frequently an inclination to laughter. After the lapse of about a minute, the true action of chloroform as an anæsthetic commences. The use of this term

* In experiments upon animals, the committee of the Medical and Chirurgical Society found that the hæmadynamometer having been applied, and small doses of chloroform having been administered, the column of mercury at once rose, indicating pressure of blood upon the artery. "This early elevation of the mercury in the hæmadynamometer must, therefore, on the whole, be considered to indicate that the immediate effect of small doses of chloroform on the heart is to stimulate its action."

anæsthetic is sometimes ill considered. An anæsthetic is a substance capable of abolishing the function of sensation; but we know of no agent acting upon the whole system capable of accomplishing this and this only. True anæsthetics are local anæsthetics. Cold and certain preparations applied to the skin are capable of depriving it of its sensibility; these are anæsthetics in the restricted sense of the term. Chloroform or ether administered cause not only loss of sensation, but also loss of motion, of perception, thought, consciousness, and many of the manifold attributes of the nervous system.

The distinctive sleep, therefore, commences—the narcosis. The senses become affected; frequently the sounds in the room are exaggerated in their intensity, the ticking of the clock becomes like the falling of a ponderous hammer. The surrounding objects become dim, and as it were dissolve in light, and then a veil enwraps them all. There is very frequently still an exhilaration, a disposition to laugh, talk, or sing. Dreams and fancies occur—temporary mental impressions which are effaced and forgotten when the narcosis is prolonged. A strange effect is the production of the phenomena of narcotic reminiscence. Events of the past life may be recalled, conversations may be repeated, and actions reproduced. A sailor will go through, with imaginary ship-mates, his nautical manœuvres, or sing his sea songs. I have heard a young girl, throughout the whole course of a surgical operation, sing "Beautiful Star" correctly, word for word and note for note. Hymns and prayers are often given with distinct utterance. All this time sensation has been gradually subdued: first of all heightened local sensibility (pain) has been abolished, then common sensibility itself. The sensibility, however, of all surfaces does not disappear at the same time. The conjunctiva retains sensibility after the skin has lost it, and the sensitive portions of skin in which the nails are embedded are the last to lose sensibility. Almost "pari passu" with loss of sensation, is loss of the power of motion—acinesia—a progressive debility ending in a total extinction of power. Just at the time that sensation is quite abolished, there occurs a muscular tremor—a struggling, slight if the chloroform be administered slowly; occasionally violent if a large dose be given. This convulsion indicates the severance from the central nervous power. The muscles are then left to their own individual influences—to heat, electricity, and

the correlated forces—which occasion contractility, this power being no longer coördinated by the brain. It was formerly thought that coördination—the power of regulating, or symmetrically producing, muscular movements, was an attribute of the cerebellum; and that the abolition of this function was an evidence of the later stage of chloroform-influence, the cerebellum being the last of all the central portions of the nervous system to be overcome except the medulla oblongata. It is certain now that this property—a property which associates muscles together and makes a proper series of them act in concert—belongs not peculiarly to the cerebellum, but to the whole nervous system. Hereto tend the wonderful symmetry of the brain-centres, the decussations of the conductors of sensation and motion, in various places, of the brain, medulla, and spinal cord. Coördination is a compound of sensation and motion, and is perfect only when these nerve-fibres are in equal degree capable of transmitting impressions from the centres. Moreover, signs of its compromise, far from being the latest, are among the earliest signs in narcotism, as shown by the imperfect attempts at articulation, and the vain efforts often made to grasp the hand.

During this time that chloroform has been administered, (these two or three minutes,) there is a great loss of sensation, although there is great capability of muscular movement, and a considerable amount of mental appreciation. Mr. Coleman relates how that he, in this stage of chloroform-influence, extracted his own tooth without feeling any pain whatever, and on another occasion incised the sensitive structures covering an abscess near his mouth. This consideration is very important, because I am sure that many operations could be done in this stage instead of being deferred to the period of complete unconsciousness. There may often seem to be pain when there is really none; we must not allow our sympathies to misinterpret signs. If the skin be pricked in the early stage of narcosis, there will be flinching, and probably a cry. The assurance will however very likely be given, after it is all over, that no pain has been felt. The other day I gave chloroform to a lady for the purpose of the extraction of a tooth. As the dentist extracted, the lady screamed, immediately adding, "Oh, excuse me for having had the nightmare!" Analogy with animals tells us that those signs which we are accustomed to associate with pain, are not always expressions of pain, for

many of those writhings and shriekings which seem to be evidences of suffering exist under circumstances in which none can be felt. A headless fly, fish, or worm will exhibit these signs. Animals that fight with their hind legs use them vigorously at any irritation, even after decapitation (Conf. Lewes, 'Sea-side Studies'). We well know that frequently if the sole of the foot of a completely paralysed limb be tickled or irritated, the leg will be forcibly drawn upwards. It would seem here that the patient must experience the sensation or feel the pain; and yet he will say that he has felt none whatever. Infants are occasionally born with only a rudimentary brain, who, on the application of stimuli, comport themselves as if pain was experienced. Both in them and in the trunk of a decapitated insect, if irritation be applied to any part, the same actions occur which would have been evidences of pain if such could have been felt. "The injured part contracts, is congested, swells, and inflames; the animal writhes, tries to escape, leaps, defends itself, and exhibits all the signs of suffering, although it is incapable of sensation."*

These signs and actions therefore come under the category of reflex. It is important to give these considerations due weight, and to urge upon sympathising relatives who may happen to be in the room at the time of an operation, that they must not misconstrue these effects; and must not in their hearts condemn the doctor who, having an agent in his hands capable of subduing pain, withdraws it to all seeming before sensation is abolished.

About four minutes having elapsed, and the muscular tremor having nearly subsided, the patient is in a state of complete insensibility—every movement is involuntary, there is no pain, and very seldom any action that would give the idea of pain. The patient lies unmoved, in the attitude and with the appearance of sleep: the pupil rather contracted, the pulse beating rather more slowly, and the breathing regular as in health, though rather more shallow. The surgeon does his work as the sculptor would do his.

Usually a sign of complete insensibility is afforded by the eye. If the globe be touched in its conjunctival covering, the eyelid will contract, there will be winking. I have said before that frequently the conjunctiva retains sensibility after the skin has lost it. This is the only value of the sign. When

* Unzer, 'Principles of Physiology.'

it occurs, you may be assured that there is no pain. But frequently abolition of pain will occur long before the eyelids refuse to wink, and in many cases it would be very wrong to try to push the inhalation till this sign should be attained.

The narcotic vapour is now not given continuously. The pure air should be breathed, a little chloroform being given now and then to maintain the effect as long as may be required. Sometimes, however, it is necessary to push the inhalation farther.

The patient now begins to snore, the limbs become quite relaxed, the muscles are loose and flabby, and the pupil of the eye becomes dilated. The state is one of a very deep sleep—of coma.

I have thus given the broad outlines of the progress of narcotism when chloroform is administered. It is well next to make a separation of these signs to establish certain landmarks.

The first signs, those of exhilaration, are common to all the agents which produce insensibility. We exclude these from the distinctive effects. I consider it of most practical importance to divide the march of chloroform narcotization into three stages characterised by these signs. First, Perversion of Consciousness; second, Abolition of Consciousness; third, Muscular Relaxation. The only difficulty is the division of the first stage from the second. I have said that the sign afforded by touching the eyeball is fallacious. My own opinion is that the muscular tremor is the best sign. Just after it has subsided there is complete insensibility.

Recovery from the effects of chloroform is generally simple and uncomplicated, exactly like the awakening from a deep sleep. There is the feeling of weariness, and the desire to be left alone. The patient at first reels and staggers like a drunken man, and the room appears to him to swim. Usually there is some nausea, which after a short time passes off, and the patient is able to control his movements.

Chloroform is eliminated from the system principally by the lungs. Every breath gets rid of it. Sometimes nature assists elimination by producing vomiting: but this is nearly always in cases (1) when a large quantity of chloroform has been inhaled, or (2) when the stomach has been loaded soon before chloroform has been given. Chloroform should never be given soon after a meal. I shall have to recur to this subject, and

shall show that it is one of the most important points for securing safety in chloroform administration—to ensure its being given when there is but a small amount of food in the stomach.

In an investigation of the effects of chloroform upon the organism, we should lose much if a part of our data were not derived from analogy. Experiments on animals have borne a most important part in the history of chloroform.

The general action of chloroform is the same in all animals, and it follows a course similar in most points to that observed in the human subject.

For the sake of example we will imagine a little chloroform poured on a piece of sponge, and held near to the nostrils of a dog: at first the animal is agitated, whines and cries. Soon the cries are replaced by groans, the limbs move convulsively, and the hind quarters become enfeebled; the skin loses its sensibility. The animal falls—still the eyelids and eyeballs are sensitive. If more chloroform be given the dog ceases to breathe by the chest-muscles. The respirations are laboured, and accomplished wholly by the abdominal muscles.

Certain variations occur according to the nature of the animal, but always the sensibility of the skin is the first to be benumbed. This is very important: for in any operation it is always the *incision of the skin* which is the most painful part of the procedure; this will confirm us in our opinion that it is not necessary to give chloroform to the extent of procuring sleep when we wish merely to incise the skin. In all animals the hind legs become paralysed first. Birds are able to use their wings when their legs have ceased to support them. Reptiles can move with their anterior segments when their hind parts are paralysed.

Dogs in some cases appear to dream: they try to use their limbs as if walking or swimming.

Animals vary considerably as to the duration of the impression which chloroform makes upon them. Reptiles continue a long time under the influence. Birds recover almost immediately. Between these limits are Mammifers. The rapidity of recovery from the effects of chloroform is in a direct ratio with the energy of respiration.

The re-establishment of breathing is followed by an increase in the force of the heart. The animal winks, dilates its nostrils, and breathes with its chest. Then it recovers the power of

movement of its head and forelegs; there is always more persistent weakness of the hind quarters. Then, the animal having recovered movement, becomes active, trying to run here, there, and everywhere, as if nature had taught it to increase by exercise the rapidity of its breathing, and so get rid of the chloroform and cause a more perfect aëration of its blood. Chloroform in all cases is eliminated by the breath and by the skin: almost entirely by the former. It is a slow process; Lallemand, Perrin, and Duroy* detected it in the breath of a dog an hour and a half after the completion of the inhalation. In cases in which large doses have been administered suddenly, the chloroform, if recovery occur, is got rid of more rapidly than when small doses have been given gradually. In such instances, the symptoms of suffocation being associated with those of chloroform narcotism, a less absolute quantity is required to produce a more profound effect. The fact of the rapidity of the elimination of large doses is no argument for their employment.

After recovery from the primary effects of chloroform, there is no permanent effect either in animals or in man—the influence passes off with the sleep which it engenders.

CHAPTER V.

THE PHYSIOLOGICAL ACTION OF CHLOROFORM AND ITS ALLIES.

Before investigating the rationale of the process whereby chloroform induces its marvellous effects, it is well briefly to consider the nature of the bodies with which it allies itself in the character of an agent for the abolition of pain. The differences are only those of degree between narcotics which pro-

* "Du Rôle de l'Alcool et des Anesthésiques dans l'Organisme," 'Recherches Experimentales,' 1860, p. 352.

duce insensibility by being taken into the stomach, and those which accomplish the same by being absorbed by the lungs. Our province is more immediately with those which act by inhalation. The following table presents the main features of their differential peculiarities (see next page).

In a cursory review of these agents allied in the one property of causing abrogation of sensation and of certain of the functions of the nervous system, many points of interest present themselves. In the first place, their plan of action in the production of insensibility is one and the same. They each and all produce (1) a Stimulus—an excitation of the functions. (2) a Suppression—a retardation of the functions. According to their dilution with air are these stages prolonged or modified. A small quantity, much diffused, entering the system gradually, prolongs the period of stimulation. A large quantity entering suddenly collapses the functions—the sudden stimulus becomes sudden extinction.

They do not all influence the processes of Volition, Sensation, and Mind alike; the abrogation of sensation is common to all, the power over motion is unequal. Chloroform and ether alone produce complete muscular relaxation; in the others, this is only attained at the confines of death. With the majority the period of complete insensibility is accompanied by more or less agitation of the muscular system. The mental processes seem to be affected less by amylene than by any other of the allied bodies.

These considerations point a moral. The use of vapour-medicines, whether for the subdual of the capability for pain (anæsthesia), or for the general treatment of diseased conditions, is in its infancy as a science. The principle of selection has to be carried into it, and doubtless the results will be of never-ending value. We have no need to speak of chloroform as if, for these things, it were the only agent placed into our hands. Its allies hold themselves up to our consideration, a too much neglected tribe. Thus, supposing our object is to induce a sufficientdegree of benumbing of sensibility that a slight and quickly accomplished operation may be performed, amylene presents itself to us, producing but a slight effect upon the profounder functions; banishing pain for the time; rapidly eliminated; and, therefore, its inhalation being suspended, its effects passing off almost immediately. Suppose we wish to reduce a dislocation, and desire that the muscles should be for a con-

CLASSIFICATION OF AGENTS HAVING THE PROPERTY OF PRODUCING NARCOTISM BY INHALATION.

	Agent.	Nature.	Chem. Comp.	Peculiarity of Action.	References.
1	Carbonic Acid	Gas	CO_2	Used diluted with air produces perfect anæsthesia. Its effects pass off almost instantaneously after inhalation has been suspended. Blackens blood.	Ozanam, 'Arch. de Med.,' 1858, p. 497; 'Herpin de Metz.,' ed. p. 627. Lallemand, Perrin, and Duroy; 'Du Rôle des Anesthésiques,' p. 405.
2	Carbonic Oxide	Gas	CO	Occasions violent muscular action; effects pass off slowly. Sometimes persistent paralysis of motion. Reddens blood.	Tourdes, 'Comptes Rendus,' 1857, p. 492; Ozanam, 'Arch. de Med.,' 1857, p. 159; Bourdon, 'Des paralysies consécutives a l'asphyxie par les vapeurs de charbon.' Paris, 1843.
3	Nitrous Oxide	Gas	NO	Produces excitation and exhilaration. Has been tried in the human subject, but has proved dangerous.	Morton (vide chap. 1), 'Dental Review,' April, 1864; 'Dental Cosmos,' November, 1863.
4	Coal Gas	Gas	C and H in varying proportions	Recommended as safe by Nunneley, but has produced symptoms of danger in animals.	Nunneley, 'Trans. Prov. Med. and Surg. Assoc.,' 1849.

5	Olefiant Gas	Gas	C_4H_4	In small doses produces sleep with very slight affection of sensibility. In larger, symptoms of danger. No sufficient line of demarcation between these effects, therefore dangerous.	Nunneley, loc. cit.
6	Fumes of Lycoperdum Giganteum	Vapour	C, H, N, and O	Anæsthesia complete and safe. Reddens venous blood. Action lasts considerable time.	Richardson, 'On Teeth,' p. 243.
7	Alcohol	Liquid	C_4H_5O, HO	Produces in animals by inhalation all signs of anæsthesia. Insensibility profound and prolonged.	Nunneley. Taylor, 'On Poisons,' p. 721.
8	Aldehyde	Liquid	$C_4H_4O_2$	Produces embarrassing dyspnœa, like severe fits of spasmodic asthma; cough and spasm of throat. Sensibility not abrogated, even when respiration is stertorous. Causes much muscular contraction. Recovery from effects rapid.	Miller's 'Chemistry,' vol. iii, p. 131; Kidd, 'On Anæsthetics,' p. 44, Lallemand, &c., p. 99; Simpson, 'Monthly Journal of Med. Sc.,' 1847, p. 740.
9	Acetone	Liquid	$C_6H_6O_2$	Produces dyspnœa and bronchial irritation.	Simpson.
10	Sulphuric Ether	Liquid	$(2C_4H_5OS_2O_6)$	Period of excitation long. Insensibility more prolonged than in case of chloroform. Muscular relaxation in later stages greater.	Lallemand, Perrin, and Duroy, p. 364; Anstie, 'Stimulants and Narcotics,' p. 289.

	Agent.	Nature.	Chem. Comp.	Peculiarity of Action.	Reference.
11	Nitrate of Ethyl	Liquid	$C_4H_5ONO_5$	Easy and pleasant of respiration; rapid and powerful as an anæsthetic, but causes much headache and giddiness.	Simpson, 'Month. Jour. of Med. Sc.,' 1847, p. 740.
12	Hydrochloric Ether	Liquid	C_4H_5Cl	Said by some to be powerful, by others considered of low powers as an anæsthetic. Very volatile and difficult of management.	Simpson, loc. cit.; Nunneley, 'Prov. Med. and Surg. Trans.'
13	Mono-Chloruretted Chloride of Ethyl	Liquid	$C_4H_4Cl_2$	Rather slower in action than chloroform. Causes much muscular rigidity. Less volatile than chloroform. Period of recovery slightly more prolonged.	Snow, p. 420.
14	Bisulphide of Carbon	Liquid	CS_2	Powerful in action, but of too repulsive an odour.	Simpson, 'Pamphlet,' 1847; Snow, 'Med. Gaz.,' 1848; Miller's 'Chemistry,' vol. ii, p. 586.
15	Oil of Turpentine	Liquid	$C_{20}H_{16}$	Produces anæsthesia, but is irritant in action. Symptoms of danger in cases of animals.	Nunneley.
16	Amylene	Liquid	$C_{10}H_{10}$	First excitement slight, and of short duration. Then, long stage of incomplete anæsthesia. Tendency to	Lallemand, &c., p. 381; Snow, p. 372.

				muscular convulsions. Does not produce muscular relaxation. Recovery from all effects extremely prompt.*	
17	Kerosolene	Liquid		Produces perfect anæsthesia, but feebleness of pulse and muscular rigidity. Is rapidly evolved.	Bigelo, 'Boston Med. Journ.'
18	Tetra-Chloride of Carbon.	Liquid	$C Cl_4$	Causes, first, muscular movement and excitation of circulation. Secondly, arterial contraction and anæsthesia. Thirdly, when long continued arrest of respiration. Fourthly, arrest of circulation. Tendency to cause muscular rigidity.	Dr. John Harley, The Author.
19	Chloroform	Liquid	C_2HCl_3	Freely diluted, produces effects similar to ether. Its action being continued, it produces its special effect, rapid muscular relaxation. Concentrated atmospheres act almost as the body last on the list.	——
20	Hydrocyanic Acid	Liquid	HC_2N	Most powerful anæsthetic known; rapid and dangerous. Causes tetanic convulsions and muscular rigidity, and paralyses the heart.	Nunneley. Richardson, 'On Teeth,' p. 245; Taylor, 'On Poisons,' 1859, p. 636.

* Two deaths occurred from the use of so-called amylene by the late Dr. Snow. Dr. Thudichum has since observed that the liquid employed, being analysed, was found to contain no amylene whatever. It was a collection of indeterminate hydrocarbons.

siderable period lax and unresisting; ether offers itself as most suitable. In the wide medium, when we desire abolition of pain, rest of muscle, absence of consciousness, chloroform is the agent to be chosen. In the hereafter, it is more than probable that we shall be able to carry still further the principle of selection. We may be able to command in a much more perfect manner abolition of sensation, abolition of motion, or abolition of consciousness at our will.

Various circumstances in connection with the individual properties of these substances modify the action which they have upon the system. Their diffusibility, volatility, solubility, all influence their effects.

Thus, hydrocyanic acid, highly volatile and soluble in water, is diffused throughout the blood in an inconceivably short space of time—a few seconds suffice to manifest its fatal effects, and in a few seconds its diffusion throughout the blood is manifest to tests.*

Great varieties occur in the degrees of solubility of these bodies. Thus while water can hold in solution $\frac{1}{9}$ of its weight of ether, it dissolves only $\frac{1}{280}$ of chloroform and $\frac{1}{9300}$ of amylene. From this it may be inferred that the quantity *inhaled* is not the quantity *absorbed*. The amount which it is necessary for the blood to retain for the production of narcotism varies with each body.

An indeterminately small quantity of *Hydrocyanic acid*, or 2—4 grains of *Amylene*, or 18—24 minims of *Chloroform*, or 4 drachms of *Sulphuric Ether*, will cause all symptoms of anæsthesia; and a much larger quantity of *Alcohol* is required to the same end.

The unity of plan in the action of these bodies cannot be too strongly asserted—it is true, not only of these vapour-medicines, but of their allies which are taken in the solid or liquid form. Opium, Indian hemp, chloroform, and carbonic acid, are similar in their effects, concurrent circumstances only modifying their action.

In the consideration of this question, a point is often too much forgotten—their local action. It is of the same sort as their general action, but the forces are unequal. If chloroform be applied to a raw surface, its first effect is stimulation—pain; its second effect, destruction—abolition of pain: so, if

* Taylor 'On Poisons,' 2nd ed., p. 65.

inhaled, its first effect is stimulus—exhilaration; its second effect, partial destruction—narcosis. There is no need to explain the early effects of stimulant-narcotics by supposing a subtraction of nervous power. Small doses of alcohol do not suspend nervous action; it is absurd to suppose that in the earliest stage fancy is set free because reason is restrained. There is an increase of all the powers, the circulation is accelerated, the sympathetic is not less active, but more active; motion and sensation are exaggerated.

All these bodies act by absorption into the blood. Theories which have explained their action on other grounds have all, as we shall presently see, exploded. Chloroform, whether injected beneath the skin, or swallowed into the stomach, or thrown into the abdominal cavity, or inhaled by the lungs, produces a train of symptoms essentially identical. Subcutaneously injected, it manifests its local caustic action at the point of injection—swelling, redness, heat and pain; but then comes its period of absorption, and there is the production of narcosis. When large doses of chloroform have been swallowed, there have occurred—first, irritation of the lining membrane of the stomach; secondly, the ordinary symptoms of narcosis and coma. Thrown into the abdominal cavity, there is, first, deep congestion; but the volatile fluid being rapidly vaporised it is rapidly absorbed, and symptoms identical with those produced by inhalation rapidly supervene.

The identity of these signs with those produced by opium or by Indian hemp is sufficiently evident.

Physical causes can explain the endurance or evanescence of the signs in case of the different narcotics. Opium having entered the blood must be eliminated by the kidneys, or by a process of slow combustion—its effects are long persistent. The volatile anæsthetics, however absorbed, are rapidly exhaled by the lungs; hence their effects are less lasting. In the process of inhalation there is constant exhalation; every breath which draws the vapour into the lungs is followed by one which drives a certain portion of the vapour out of them; so there is a delicate balance maintained which may be overweighted on either side. The continuance of the vapour-atmosphere induces a preponderance of imbibition over exhalation, with the symptoms of narcosis; its discontinuance allows a preponderance of elimination with the symptoms of recovery. The value of the inhalation-process, is evidenced by the control

that we can exert upon the conditions induced. When chloroform is swallowed, elimination takes place in the same manner, but narcosis is more lasting because the blood is more heavily burdened.

The persistence of narcosis, therefore, varies—first, according to the volatility of the agent; secondly, according to its solubility; thirdly, according to its destructive power upon the blood. All these causes combine to modify the action of each anæsthetic.

We will take four examples. Suppose that *Alcohol* has been absorbed to the production of complete inebriation. Here the blood is impregnated with a large quantity of fluid with which it is readily miscible. The noxious fluid is eliminated by a series of slow processes—part is thrown off by the breath, part by the kidneys, part by metamorphosis, by its change into other compounds;* hence the symptoms of intoxication are of long continuance.

When *Amylene* is inhaled, owing to its very slight solubility, only a very small portion is taken up by the blood. When no more of the vapour is presented to the lung, the very small proportion of this extremely volatile liquid is readily exhaled, and the system returns rapidly to its state of health.

Carbonic acid manifests its effects only while it is inhaled. Its presence in the blood suppresses its functions for the time, but the breath soon gets rid of it, an inspiration of pure air revivifies the blood, and the functions are restored.

Carbonic oxide acts differently. A priori, from its gaseous nature, we should fancy that its effects would be as transitory as those of carbonic acid; but it is not so. The blood-globules under its influence are radically altered, their function is not only *suppressed*, but to an extent *destroyed*. Hence not only is recovery prolonged—a sufficient aëration of the blood being tardily induced—but frequently symptoms of a persistent nature are left behind.†

Having considered chloroform in these its relations, we will now inquire, upon what element of the organism is its operation first directed? The early notions on the subject—and

* The author considers that the assertion of MM. Lallemand, Perrin, and Duroy, that the whole of the alcohol imbibed passes from the economy entirely unchanged, is abundantly disproved.

† Bourdon, 'Des paralysies consecutives à l'asphyxie par les vapeurs de charbon.' Paris, 1843.

these are now the generally received ideas—were, that chloroform, ether, and the volatile anæsthetics exerted a primary action upon the brain and central nervous system. "It has been supposed that the anæsthetic is absorbed; that the general insensibility is the result of its contact with the nervous system. It exercises a sort of stupefying action on the system, for which it seems to have an affinity of election." So it determines the suspension of cerebral action. ('Arch. de Med.,' 1858.) Flourens first showed this in the case of ether—how the centres of nerve-force lost their attributes in regular succession: first, the cerebral hemispheres theirs, the intellect; next, the cerebellum its power of co-ordination; thirdly, the spinal cord its conduction of sensation and motion; finally, if the action were continued, the medulla oblongata its power of continuing the functions of organic life.

This doctrine of the elective affinity of anæsthetics for the cerebro-spinal system is entirely embraced by MM. Lallemand, Perrin, and Duroy. They have established the fact that, after death from inhalation of the anæsthetic, a superabundant proportion of ether or chloroform is found in the brain and spinal cord; and therefore they argue, that (1) these accumulate therein in virtue of a particular elective affinity; and (2) thus, and thus only, are they capable of abrogating the functions of these organs.

The last writer on this subject (Dr. Anstie) thus expresses himself on the active influence of chloroform: "Like alcohol, chloroform rapidly *attacks* the cerebral hemispheres."

Now, all these observations point to one assertion—one fact unquestioned by these observers: that the anæsthetic is absorbed; that (supposing it to be chloroform) it circulates as chloroform; that it chooses out the cerebral nervous system in which to store itself up, and on which to exert its power.

A primary difficulty has been advanced to this theory by the observations of Messrs. Faure and Gosselin. The first of these experimenters exposed the brain of a dog, and poured chloroform thereupon; no diminution of sensibility followed. He divided the organ, and applied chloroform; still there was no symptom of narcosis. He removed portions of the brain of a narcotised animal; recovery from the somnolence occurred as in ordinary cases. M. Gosselin injected chloroform into the carotids, and failed to produce anæsthesia.

These experiments tended to show that chloroform, applied

to, or circulating in the brain, *merely as chloroform*, fails to produce anæsthesia.

To some, therefore, this paradox of elective affinity has been the occasion of a deeper investigation. Snow, Nunneley, Richardson, Faure, Gosselin, and others, have advanced arguments which dispute the doctrine, and point to a more universal cause for the phenomena of etherisation—a cause that acts,

"Not by partial, but by general laws;"

the element of the organism to which these observers point, as the first acted upon by etherisation, is the blood.

It may be well to consider what first occurs in the production of anæsthesia by a volatile agent. First, a quantity of the vapour, commingled with atmospheric air, is breathed; that is to say, it is brought into contact with the six hundred millions air-cells of the human lungs. It is thus exposed to a vascular surface, the superficial extent of which has been estimated by Lindenau at not less than 2642 square feet. In the ordinary process of inducing anæsthesia, fifteen or twenty cubic inches of the anæsthetic mixture, fifty or sixty times over, are brought into contact with this surface. Obviously, it may do one of two things:—it may be absorbed into the fluid part of the blood, be projected throughout the body, and may manifest its effects by its direct action on the central parts of the nervous system; or it may act upon the blood, modifying its vitalisation—modifying that interchange of elements necessary to perfect health. It is not doubted that there are certain gaseous bodies capable of thus influencing blood-aëration, the action of which is precisely analogous to the other anæsthetic agents. Inhalation of dilute *carbonic acid* gas causes all the phenomena of anæsthesia which are produced by inhalation of chloroform. The only differences observable are, that the effects are more fugitive, and the pulse and respiration are uninfluenced throughout the progress of the inhalation. (See 'Lallemand, Perrin, and Duroy,' p. 406; 'Ozanam, Arch. de Médicine,' 1858, p. 497; 'Herpin de Metz,' id., p. 627.)

Inhalation of *carbonic oxide* produces a similar train of symptoms, plus a greater degree of muscular agitation.

It is not doubted that the inspiration of these gases causes a direct influence upon oxygenation, and thus produces the physiological effects due to them. Carbonic acid induces a

degree of direct asphyxia, by loading the blood with that which, in the nature of things, it is its function to eliminate. Carbonic oxide acts directly upon the blood-globules. It poisons, says M. Claude Bernard, by preventing arterial blood from becoming venous. Under its influence, the altered globules no longer absorb the gas in the midst of which they lie, nor yield up the gas which they inclose. One is led, then, to the question, Wherein are the differences of action between these and other volatile anæsthetics, such as ether, chloroform, etc.? Can a more unsatisfactory answer be made to this question than that of Lallemand, Perrin, and Duroy?* "These anæsthetics, abolish, by their direct influence, the functions of the cerebro-spinal axis." They say: "We have shown that they accumulate in the nervous centres in considerable proportion. It is, therefore, natural to admit that the impregnation of the nervous mater by these anæsthetics is the determining material cause of the progressive disturbance in the functions of the nervous system." Natural? It is very unnatural that these bodies should have an ultimate action altogether different from those bodies with which they have so direct an analogy; that they should exert an affinity of choice, and store themselves up in the nervous system to produce their effects; that in their case the brain poisoning should be primary, and the blood poisoning secondary; whereas, in the cases of the other bodies, these conditions should be reversed. And all on what grounds? Merely because the liquid vaporisable anæsthetics are found in greater quantity in the brain after death than in other parts of the body—in the brain, whose soft substance gives the best conditions for the storing up of the fluid; wherein the conditions favorable to exosmose are in their highest degree. Even this can be carried to a reductio ad absurdum; for in the liver is found the next large proportion of chloroform (a very considerable quantity). Changing the premises, would MM. Lallemand, Perrin, and Duroy attribute nervous power to the liver? Moreover, if it is by this soaking of the brain, as it were, with chloroform, that anæsthesia is accomplished, how is it that the effects of chloroform — the phenomena of narcosis—so readily pass off?

Further analogy will shew the insufficiency of reasoning

* *Loc. cit.*, p. 418.

whereby these gaseous agents, carbonic acid and carbonic oxide, have been denied the very name of anæsthetics—whereby these, whose action in abolishing sensation is so complete, have been said to be no anæsthetic agents, properly so called, but only pseudo-anæsthetics. The similitude of the symptoms of induced anæsthesia with those of suffocation is remarkable. Flourens, who was the first to trace the gradual action of ether upon the nervous centres, and who was very prominent in urging the affinity-to-cerebral-matter theory, gave it as his opinion, that it was impossible to see chloroform administered *in a single instance* without being struck with the resemblance of the phenomena to those of suffocation. There is scarcely any scientific phenomenon more common than the production of anæsthesia under the causes of asphyxia. (Conf. Faure, 'Arch. de Méd.,' 1858, p. 585.)

Consider how our faculties and functions are maintained during life and health. By the circulation throughout our body of the blood, which receives from the air we breathe a due supply of oxygen for its vitality: this supply of oxygen is a necessity for perfect life; no vital change can go on without it. In a normal state the blood charged with it permeates everywhere throughout the system, undergoing that wonderful process of combustion, ending in the excretion of carbonic acid, which causes the heat of the body—it reacts with every tissue developing electric and other correlated forces, obedient to and yet producing the unknown vital force. Perfect venous blood, with perfect arterial, produces electrical phenomena evident and demonstrable. The sum of all these changes is life with its perfect sensation, perfect volition, and perfect consciousness. This interchange of elements, the absorption of oxygen, the excretion of carbonic acid, not in the lungs only, but throughout the whole system, is therefore the index of perfect life. Anything which interferes with this process, either by preventing the supply of oxygen or by so altering the blood that though the oxygen be present it cannot take it up, paralyses the functions of life.

Nunneley believed that anæsthetics acted in virtue of the carbon which they contain; and their action was more powerful as their carbon was more abundant. But it must not be forgotten that nitrous oxide and certain non-carbonized bodies are anæsthetic agents—even oxygen (in a modified condition) itself. Robin considered that chloroform and ether

impeded the entrance of oxygen into the blood. Snow, in lectures published in the 'London Medical Gazette' (1848-51), held this view; and the researches of Faure, Jackson, Richardson, and Geo. Harley, point to the same.

Both analogy, therefore, and observation, show that the phenomena of narcosis are due, not to an especial influence exerted on the nervous system, but to the suppression of that action which the blood exerts normally upon the system. M. Faure says: "It is not an active phenomenon corresponding to a new state, but an altogether passive condition, resulting essentially from the suppression of the normal state."

Given, then, that anæsthetics, such as ether and chloroform, act by suspending the due oxygenation of blood, how do they effect this suspension? Obviously, either by acting upon the blood itself, or upon the structures through which oxygen passes into the blood. M. Faure adopted the view that the latter is the part acted on; that the alteration of hæmatose was due to the effect of the anæsthetic—a destructive effect—upon the mucous membrane of the lung. A very slight examination proves the entire untenability of this theory. For (1) it is abundantly proved that chloroform, as previously stated, manifests its narcotic effects however it may be absorbed. I am induced to linger for a while on this point because the dictum of Lallemand, Perrin, and Duroy (whose hypothesis of the determination of chloroform to the brain has proved so erroneous) is, "Le chloroforme liquide n'est pas absorbé; il n'a point d'action generale." Absolute proofs of the falsity of this are afforded by recorded cases in which chloroform has been swallowed in large quantities. A case is even related in the work of the French savans themselves. It is only necessary to read these cases to see how completely the phenomena correspond with those produced by inhalation.* (1) Dr. Anstie experienced all the signs of narcosis from having swallowed forty-five minimums of chloroform.† (2) Injections into the peritoneal cavity of animals also cause all the symptoms of anæsthesia.‡ (3) Injections beneath the skin also produce narcosis. "In numerous ex-

* See a most interesting case recorded in 'Med. Times,' May 10th, 1862, in which death occurred from exhaustion after prolonged narcosis. See also 'Med. Times,' May 30th, 1862.

† 'Stimulants and Narcotics,' p. 359.

‡ *Loc. cit.*, p. 366.

periments which I have made (with chloroform) in animals," Mr. Hunter states,* "I find that the effect on rabbits when injected in small quantities is analogous to that of opium in small doses, but in larger it is more productive of anæsthesia than of coma;" and Mr. Hunter relates a case in which the subcutaneous injection of thirty minims of chloroform relieved the pain of neuralgia in a patient of his own, and induced sleep in fourteen minutes.

These proofs of the absorption of chloroform completely invalidate the theory that the suppression of aëration is due to a local action upon the lungs, but further, (II) It is a commonly observed fact that the lungs after death from chloroform do not show any signs of congestion, or of alteration of their tissue; most frequently they are in colour. (III) Lastly, the theory is overthrown by the facts of the rapid recovery from chloroform-narcotism. If these alterations of the tissue of the lung did occur, how certainly would they compromise life! with what tardiness and difficulty would respiration be established.

The remaining hypothesis is, therefore, that the action of narcotics is directly upon the blood—that narcosis is suspension of oxygenation.

CHAPTER VI.

THE ACTION OF CHLOROFORM AND ANÆSTHETIC AGENTS &c., UPON THE BLOOD AND THE CIRCULATION—THEIR MODUS OPERANDI.

In the first place it is necessary to observe that an investigation into the exact influence of agents upon the blood and upon that series of metamorphoses which constitute life approaches to the most abstruse of problems. We come to a point where our power to demonstrate the "modus operandi" stops. Analogy will tell us much.

Carbonic acid is seen at once to act upon the blood. It makes bright arterial blood dark and venous—its effects are manifestly due to this imperfection of the circulating fluid.

* 'Med. Times,' Sept. 10th, 1859.

Carbonic oxide also evidently acts upon the blood, but in a different manner. It reddens it, making venous blood arterial; it paralyses the blood-globules.

If alcohol be shaken with blood it causes it to assume a brick-red colour, and no amount of agitation with air will again arterialise it.

Ether mingled with blood gives it a dark purple colour. It not only prevents rëarterialisation, but it dissolves the blood-corpuscles, setting free their hæmatin. Even in the circulating blood of an etherized animal the change of colour has been noticed.

Chloroform turns the blood of a brilliant scarlet colour. It so acts upon the corpuscles as to alter their physical character and to reduce their pigment. Thus it gives rise to (1) a colouring matter of a vermilion tint held in suspension: (2) a precipitated dirty red proteinous substance. Chloroform has not such a power of universal solution of the blood-corpuscles as ether has, but it destroys great numbers, setting free their hæmatin and causing crystallization of it. Chloroform shows no influence on the circulating blood apparent to the eye; but the colour has been frequently noticed during life to be brighter than natural.*

Whatever may be then its effects evident to the senses, it is an ascertained fact that chloroform has the property of diminishing the power of the organic constituents of the blood to unite with oxygen and to give off carbonic acid. This is a power which it shares with all other narcotics, as has been established and proved by Dr. George Harley.†

If atmospheric air be agitated with pure blood, its composition is thereby altered. The unaltered atmospheric air contains about 200 parts of oxygen in 1000. By contact with the blood so much of this oxygen is absorbed, that only about 70 parts in 1000 are left; the 130 parts have disappeared to oxygenate the blood; but the blood has parted with a large proportion of carbonic acid; normal air contains only about 2 parts of carbonic acid in a thousand—after agitation with blood it contains about 340 parts. Hence, when normal blood

* Many of these observations have been taken from Dr. George Harley's papers, an abstract of which is given in the 'Pro. Roy. Soc.,' vol. xiii, p. 157. The author's experiments confirm them.

† 'Brit. and For. Med.-Chir. Review,' 1856, p. 429.

is agitated with air there is an energetic interchange of the component elements of each.

Suppose the blood, instead of being pure, be mingled with chloroform, morphia, or even alcohol, these results are strangely modified. The blood refuses to take up so much oxygen. In the remaining air 160 or 180 parts per thousand are found instead of 70 parts, when the blood is normal. The energy of the blood to absorb oxygen, therefore, is, by the influence of the narcotic agent, diminished by more than one half. But the proportion of carbonic acid after agitation is less than in the case of normal blood. Only about 200 parts will be found instead of 340. Hence, the energy of the blood to throw off its carbonic acid is, by the influence of the narcotic, diminished about one third.

The common property therefore of narcotics and anæsthetics is to diminish the energy of interchange between the constituents of the air on the one hand and those of the blood on the other. Experiment shows this beyond a doubt. Dr. George Harley, besides the experiments recorded in the year 1856, has made an abundance of confirmatory observations. To a paper lately read before the Royal Society, the author acknowledges his indebtedness, and he is sure that Dr. George Harley's observations on this subject will be recognised as among the most valuable contributions to science which Physiological Chemistry has ever initiated.

The next question occurring is the nature of the change which produces these results.

Does the chloroform undergo a change in the blood? Probably not: for in the great majority of cases no derived product has been detected; and, in most instances, the chloroform can be recovered unchanged. Dr. Jackson, however,* has cited a case of death from chloroform, in the post-mortem examination of which he found formic acid and chlorine, but no undecomposed chloroform. Here the anæsthetic (terchloride of formyle) had robbed the blood of its oxygen, and had thus become formic acid:

$$C_2H\,Cl_3 + 3\,O = C_2HO_3 + 3\,Cl.$$

Experience, however, has shown this change to be exceptional.

* 'Boston Medical Journal,' March 28th, 1860.

Combustion theory. It has been supposed by Dr. Snow and Dr. Richardson, that anæsthetics exert their power in retarding oxygenation in virtue of their property as non-supporters of combustion.* It is quite true that nearly all narcotics in vapour, or narcotics diffused through air, cause the extinction of a flame plunged therein. That non-support of combustion and narcosis stand in relation of cause and effect, however, is a different matter; for, in the first place, the "post hoc" argument is of little value, because the class of Non-supporters of Combustion is so large, whilst the class of Supporters of Combustion is so small. The argument loses still more of its force when it is considered that nitrous oxide, which abundantly supports combustion, is an undoubted anæsthetic. Moreover, the energy of an anæsthetic is in no wise an indication of its power to arrest combustion. An atmosphere of hydrocyanic acid, which would poison an individual, could yet support flame, and a proportion of ether vapour which might be readily breathed without narcosis, could yet put an end to combustion.

Action on the Blood-corpuscle. It will be seen that the vaporisable anæsthetics have a great influence upon the form and integrity of the blood-corpuscles—this was first pointed out by the author in a paper read before the Royal Medical and Chirurgical Society.

What is the function of the red blood-corpuscle?

1. It ministers to the nutrition of muscle and of nerve. The great bulk of the corpuscle, its globulin, is closely related in its composition to the substance of muscle. With nerve it is allied by the existence in both of a quantity of phosphorized fat.

2. It ministers to excretion, removing in its return (venous) current the effete carbon in the form of carbonic acid.

3. As the great constituent of the blood, it, in its relations and combinations, maintains and fosters those electrical changes which are the necessary concomitants of perfect life.

On the blood-corpuscles depend the vital activity of the nervo-muscular apparatus—and, moreover, as a general rule, the physical power of the organism is in a direct ratio with their amount and the perfection of them.

* See report of paper read by the author, and discussion thereupon, 'Med. Times,' September, 1864.

Nutrition and elimination in our body are constant, incessant. Interruption of either immediately causes interruption of function.

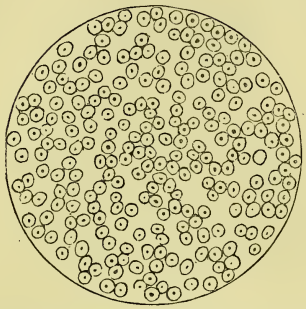
In the circulation of blood in which a narcotic is absorbed, there is interruption—first, of the function of the blood-corpuscle; secondly, of the function of muscle and nerve, to the integrity of which the blood-corpuscle ministers.

Dr. G. Harley has abundantly shown that the blood, under the influence of chloroform, cannot supply the normal amount of oxygen to the tissues, and cannot excrete the normal proportion of carbonic acid. The observations of MM. Lallemand, Perrin, and Duroy* would seem to imply that *even the fats* of the blood are acted on by the chloroform:—"The blood, both arterial and venous, is covered on its surface with glistening particles which have the appearance of oil-globules. These globules disappear with the anæsthetic state." These authors do not give any explanation of the occurrence. As, therefore, there is in the case of chloroform-narcotism, blood, circulating throughout the body, which is incapable of continuing the normal nutrition of the nervo-muscular system, and of removing its effete particles—as the normal molecular relations between the blood on the one hand and the tissues on the other are disturbed—the nervo-muscular functions are also interrupted, and hence the phenomena of narcosis.

Causes of the differences in colour of the blood. It is especially to be borne in mind that the differences in colour of arterial and venous blood, and in blood under the influence of certain agents absorbed into the system, are due less to change of composition than to change of form. The blood is darkened by whatever tends to distend the corpuscles, making them more and more convex; brightened by whatever tends to empty them, making them more and more concave. According to the author's observations, the agent which has the greatest effect in distending the blood-corpuscles is hydrocyanic acid; ether possesses the same power to a less degree. Carbonic acid distends the corpuscles, carbonic oxide tends to empty them. Ether turns the circulating blood dark, chloroform

* Lallemand, Perrin, and Duroy, 'Rôle, &c.,' p. 291. "Le sang artériel et veineux est couvert à sa surface de parcelles miroitantes qui ont l'apparence de globules de graisse; les globules disparaissent avec l'état anesthésique. Nous avons observé le même phenomène, chez les animaux sommis à l'intoxication alcoolique."

Fig. 2.



Human blood treated with dilute hydrocyanic acid.

renders it bright. It is, therefore, not one uniform action which anæsthetics have upon the blood. There may be distension, or there may be attenuation of the corpuscles, yet, in either case, there is the same incompetency to maintain the functions of motion and sensation.

Although, as we have just said, the tendency of chloroform is to render the blood redder than natural, still in cases of death from chloroform the blood is always found dark and fluid. It is to be remembered that the deaths have usually been due, not to the progressive narcotic effect of the agent, but to a sudden suspension of motor power. The appearances of the post-mortem blood are those of sudden death from other causes.

Microscopical observations. The author, in a paper read before the Medical and Chirurgical Society, in 1861, expressed his belief that the change induced upon the blood-corpuscles was one capable of being, to some extent, demonstrated.*

Experiment 1. To a drop of frog's blood, under a quarter-inch object-glass, a drop of *alcohol* is added. The red blood-corpuscles are immediately seen to be altered. They assume a granular appearance—a nucleus becomes apparent in those in which it was not seen before. Then the corpuscles become dissolved: their outline is imperfect, many of them dissolve

* See also a paper by the author in Beale's 'Archives of Medicine,' 1861.

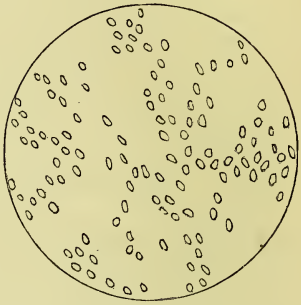
like lozenges in water (*i.e.*, giving the idea that their substance is semi-solid, not that they are shut sacs enclosing fluid);* others disappear much more rapidly, so that their solution cannot be traced. Finally, there is left in the field nothing but granular matter, and hard, irregular nuclei.

Fig. 3.



Frog's blood to which chloroform has been added. (*a*) Granular appearance; (*b*) corrugation and alteration of shape; (*c*) further alteration; one cell is seen to be very pale prior to solution.

Fig. 4.



Nuclei left after the action of ether upon frog's blood.

Experiment 2. In the same manner the blood is treated with a drop of *ether*. The dissolving power here is greater; the granular matter is not seen, there is a more complete solution. The nucleus is rendered hard, and the field soon is seen to contain nothing but nuclei and some débris of the cells.

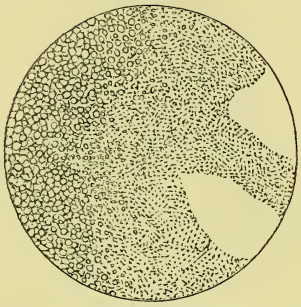
Experiment 3. *Chloroform* induces a similar solution, but in a less marked degree than ether—but it in like manner (1) corrugates the cell, (2) alters the shape, (3) destroys it, liberating the nucleus (see fig. 3).

Experiments 4, 5, and 6. If human blood be treated in the same manner by these agents, the results are similar. The solution of the corpuscles is rendered striking, because the field in which they are suspended is coloured, owing to the liberation of the colouring matter of many of them.

The effect therefore of these agents upon the blood is solu-

* Dr. Beale's observations point to the same conclusion. See paper "On Nutrition," 'Med. Times,' April 1st, 1865.

FIG. 5.



Human blood-corpuscles altered, dissolved, and destroyed by chloroform.

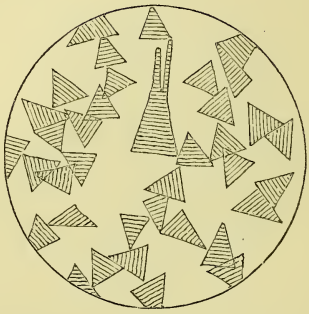
tion—destruction. At first there is a change induced upon the cell itself and upon the nucleus (in the case of frog's blood). The globulin of the blood-corpuscle is acted on as it were by a caustic. Finally, the whole corpuscle is destroyed, and its colouring matter set free. This colouring matter is capable of crystallisation.

Experiment 6. If a drop of chloroform be added to a few drops of the blood of the guinea-pig, covered with a circle of thin glass, the colouring-matter is seen to be at once set free, tinging the field, in a few hours crystals begin to form. These crystals (hæmato-globulin), thus obtained, are usually flat plates of trihedral form.

From the foregoing facts, and other considerations, the author considers that certain conclusions with regard to the action of anæsthetics are warrantable. Anæsthetics are agents which, when absorbed into the circulation, exert an influence upon the blood. They are shown to have the power of altering its *physical character* and its *physical properties.* By an action upon its constituent (proteinous) elements, they tend to alter (and by a profounder action destroy) its organic molecules. Its physical perfection being interfered with, its function is held in abeyance; the changes which contribute to constitute perfect life are retarded. Narcosis ensues; and is due, not to the influence of a circulating poison, but to the influence of an altered blood.

There is a delicate balance in the organism in a state of

Fig. 6.



Crystals obtained by the action of chloroform on blood of guinea-pig.

induced anæsthesia. On the one side is Being, robbed of many of its attributes; on the other side is Death. Compensating oxygenation maintains the one, and insufficient oxygenation induces the other.

The first effect manifested in narcosis is an irritation of the heart. All narcotics show, as a first sign, increase in the frequency and force of heart-pulsations. This then becomes a derived as well as a direct action, dependent on a cerebral as well as a cardiac cause. Of course the circulation in the brain of altered blood disturbs its molecular conditions, and hence all the mental phenomena of narcosis—hence, also, in part, the depression of circulation observed in a later stage of the course of narcosis from chloroform; for Weber and Eckhardt have established that, whilst a slight irritation of the brain exalts the heart's action, a more intense irritation causes a more moderate action.

Decreased force of general circulation is, however, not a necessary concomitant of narcosis. Ether seems to produce no enfeeblement of circulation till the respiratory powers are compromised. Herein is the difference between ether and chloroform: the first is for a long period a stimulant to the heart, and scarcely at all a depressant of it; the second very soon enfeebles the heart's pulsations.

In the experiments made by the Committee of the Medical

and Chirurgical Society,* when the hæmadynamometer was applied to an animal which was gradually chloroformed, after the transient rise of the mercury a gradual fall was noticed. The fall was greater as the influence of the chloroform augmented. There were slight variations at different periods. A slight restoration of force would at times occur, which is explained by shallow respirations occurring at these periods thus by the failure of respiration, the rate of introduction of the agent into the system was lessened, and the heart revived.

When the force of the heart's action was depressed by the chloroform, if the inspiration of fresh air were permitted, the mercury rose, the heart recovered itself. This effect could be many times repeated.

Chloroform, therefore, after a temporary stimulus, exerts a depressant action upon the heart.

In the experiments made by the Committee with ether, it was found that sometimes, even after insensibility had been induced, the mercury in the hæmadynamometer stood higher than before the administration of the ether. With ether there was failure of the force of circulation only when there was manifest failure of breathing.

The opportunities which the web of the frog's foot affords for the investigation of the phenomena of the circulation have suggested to me the observation of the same under the influence of anæsthetics. With the valuable help of Dr. John Harley, I have made a series of experiments, the results of which are epitomised in the following table. In all cases the vapour was administered by the mouth of the animal.

* "Report of Committee," 'Med.-Chir. Trans.,' vol. xlvii, p. 326.

EFFECTS OF THE INHALATION OF ANÆSTHETICS UPON THE CIRCULATION IN THE WEB OF THE FOOT OF THE FROG.

Carbonic Acid Gas.	Alcohol.	Ether.	Chloroform (dilute).	Chloroform (concentrated).
1. Increased flow of blood.	1. Increase of flow.	1. Increase of flow.	1. Increase of flow.	1. Increase of flow.
2. Contraction of artery to two thirds of its original size: soon after to one half its size. Pallor of contained blood. Circulation rapid.	2. Contraction of artery. When strong vapour was given, either by current of air blown through alcohol or by boiling the alcohol, each time there was *contraction* of the artery and increased rapidity of the circulation.	2. Contraction of the artery, persisting while frog was fully under the influence of the ether. On the injection of air into the mouth dilatation to normal calibre.	2. Contraction of artery to two thirds of original size.	2. Sudden enfeeblement of circulation. Contraction of artery transient; frequently not occurring at all.
3. Sluggishness of capillary circulation. Change in appearance of many corpuscles. Aggregations of white corpuscles. Imperfect red corpuscles, and,	3. Paralysis of motion now shown. Circulation in capillaries became slow, ending in almost stasis, first in capillaries near vein, secondly in vein.	3. Strong vapour being administered, dilatation of artery to nearly twice its normal size occurred.	3. Capillary system congested.	3. Threatened stasis.

lining vein, a number of round corpuscles apparently extruded nuclei. Capillaries apparently somewhat dilated.				
	4. Complete anæsthesia. Artery contracted almost to obliteration.	4. Great retardation of capillary circulation. Capillaries dilated and loaded. Artery dilated to twice its normal size.	4. Dilatation of artery to normal size. Application of stronger chloroform-vapour caused contraction of artery to two thirds, afterwards to one half. Afterwards dilatation as before.	4. Artery dilated one quarter more than its normal size. This presisted, and was unaffected by injection of air and any restorative means. The circulation in the capillaries was resumed, the artery continuing dilated, but without further exhibition of chloroform, the signs of stasis recurred.
	5. Profound anæsthesia. Artery became dilated.	5. Stasis.	5. Full anæsthesia. Arterial and capillary flow enfeebled, but regular.	

Briefly, therefore, the conclusions to which these observations point are as follows:—

First. In the case of all the anæsthetics employed—carbonic acid, ether, alcohol, and chloroform—there is, at first, increase of the flow of blood throughout the whole arterial system.

Secondly. The next sign is decided contraction of the arteries, the current maintaining its original force. In all cases the capillary artery was measured, as to its breadth, by the micrometer.

During the inspiration of carbonic acid, the artery may be reduced to half its original size; and in the case of alcohol, the contraction may persist almost to obliteration. Restoration to original size soon occurs after the vapour ceases to be respired, but any re-exhibition causes re-contraction. Only when concentrated chloroform-vapour is employed, the contraction is reduced to a minimum, and often passes to the opposite extreme, dilatation. It is evident that contraction of the artery may persist throughout perfect anæsthesia, and dilatation is to be looked upon as a sign of too profound an action.

These observations are wholly opposed to the view Dr. Anstie takes in his book on the 'Action of Stimulants and Narcotics.'* He considers that paralysis of the sympathetic is an early sign of narcotism.

Thirdly. Next in order is observed sluggishness of the flow of blood in the capillaries. In the case of chloroform, the corpuscles frequently show a tendency to aggregate, and toil along in an irregular manner. Under the influence of respired carbonic acid, the corpuscles become very pale, agglomerations of white corpuscles seem to choke many of the capillaries, and the returning vein is seen to be loaded with imperfect oval corpuscles, and a large number of white corpuscles (or extruded nuclei).

Fourthly. There is dilatation of the artery and increasing sluggishness in the capillary flow—then stasis.

These stages are constant in the case of the other anæsthetics, but with chloroform their duration and relation vary with the strength of the vapour employed. If a very weak atmosphere of chloroform be inhaled, the contraction of the artery is prolonged, as in the case of alcohol, and a uni-

* 'Stimulants and Narcotics: their Mutual Relation,' by Francis E. Anstie, M.D., M.R.C.P. Macmillan, 1864.

form, though enfeebled capillary flow occurs, even in advanced anæsthesia. If the inhaled vapour be strong, the stage of contraction is of very short duration; frequently dilatation rapidly supervenes, and there is a great embarrassment of the capillary circulation.

The essential concomitant, therefore, of a state of anæsthesia is sluggishness of the circulation in the *ultimate* capillaries, but withal there is a *deficiency in the supply of arterial blood.* Thus, even though the force of the current in the arteries be even augmented, their diminished calibre prevents a normal supply. As a consequence, therefore, there must be a certain retention of blood in the venous system.

A state of anæsthesia does not imply hyperæmia in any organ. In sleep, as Mr. Durham has pointed out, the brain is comparatively anæmic, and the blood in its vessels is not only diminished in quantity, but also flows with a decreased rapidity—so in chloroform-narcotism. An interesting case has been recorded,* in which the condition of the circulation in the brain was observed during anæsthesia. A patient had an extensive fracture of the cranium, which permitted a view of the encephalon. It was seen that as chloroform was administered, during the full effect of the narcotic the brain was remarkably pale, and whenever the anæsthetic influence began to subside, the surface of the brain became florid and injected.

The phenomena of anæsthesia are propagated by means of the circulation; another cause, however, being concurrent, and still further interfering with oxygenation, viz., the local action of the vapour upon the nerves supplied to the lungs—the pneumogastrics.† The sensibility of the tissue of the lung is destroyed by the narcotic vapour; the membrane lining the bronchial ramifications being insensible, these are paralysed and distended with mucus, the power of expectoration being in abeyance.‡

The tendency of the blood seems to be, at first, to excrete carbonic acid—during the early stages of narcotism this is found to be exhaled in greater proportion than in health (Ville and Blandin). At the later stages, however, this function of excretion is arrested, the proportion of carbonic acid becomes

* 'American Jour. of Medical Science,' Oct., 1860, p. 400.

† See Panizza, 'Gazette Médicale de Milan.'

‡ Lallemand, Perrin, and Duroy, p. 253.

extremely small, and, finally, can be no longer detected (Bouisson).

In narcotism the heat of the body is notably depressed—to the extent of 2°·5 to 3° c. in the case of ether-narcosis.*

The question now occurs: How far, by their influence on the function of respiration, do anæsthetics manifest their effects? The *obvious* effect of narcotics on breathing is but slight; the frequency of respirations is, in a state of anæsthesia, about the same as that in a normal state. The report of the Committee of the Medical and Chirurgical Society states (vide pp. 330—335), that inspirations become, under the influence of anæsthetics, more and more shallow. Under the influence of chloroform, "the depth of the respirations became less and less, and after the stage of perfect insensibility was reached, the amount of air entering the chest was extremely small." Imperfect inspiration, therefore, is another subsidiary cause impeding, the due aëration of the blood.

An attempt may now be made to summarise these observations:—

Narcotism (or, to speak more particularly, chloroform-narcotism) is due, not to a special poison which "mounts up to the brain," but to the influence of an altered blood. "Narcotism is suspended oxygenation." Whatever produces, to a certain extent, insufficient aëration of the blood, produces narcosis; and whatever produces narcosis, produces, by some means or other, imperfect aëration of the blood.

To produce the anæsthesia which chloroform effects, the following causes combine:

1. The special action of chloroform upon the blood preventing its oxygenation.
2. Diminished arterial supply.
3. Sluggishness of flow in the capillaries.
4. Subdual of energy of nerve-filaments distributed to the lungs.
5. Shallowness of respiration contributing to prevent free entrance of air into the blood.

We have now investigated the physico-chemical phenomena of the anæsthetic sleep. On the organic conditions of life chloroform exerts little or no influence so far as is obvious to the senses. The pulse, though at first quickened, is, in com-

* Duméril and Démarquay, 'Arch. Générales de Médecine,' 1848.

plete anæsthesia, reduced only to its normal level. The breathing is quieted, but the *rate* of the respirations is scarcely altered unless the narcotism be pushed to coma.

As in ordinary sleep, so in chloroform-narcotism, carefully conducted and no complication occurring, the organic functions continue tranquillised, but not compromised.

CHAPTER VII.

THE DANGER OF CHLOROFORM AND THE CIRCUMSTANCES WHICH MODIFY IT.

The cases of death during the inhalation of chloroform which are often recorded in the papers at once dissipate the idea that the vapour is innocuous. Every now and then these concentrate, and the public mind is wrought into a ferment: the alarm is wholesome and necessary. Yet, whenever this subject has been ventilated it has been done in a manner which is not at all calculated to conduce to valuable results. There have been wars of opinion, disputes concerning methods, questionings concerning truthfulness, bold assertions founded on individual experience; but there has been very little investigation into facts. One writer declares that chloroform should never be used; another, that its danger is almost altogether fancied; one says, people die under it from shock; another, that they die from suffocation. Some argue that it should be administered in the simplest manner possible—on a pocket-handkerchief; others urge that there should be the security of mechanical dilution with air.

The only way of ascertaining the truth, and of learning the right path to follow, is to observe what are the teachings of actual facts. Personal experience in the administration of chloroform leads one to hold certain opinions; it may tend to dogmatism; butit will be readily seen how necessary it is for this to be toned down. Thus, a person will say, "I have given chloroform in such and such a way two or three thousand times, and have

never had a fatal mishap—*ergo*, mine is the right method of administration." The answer is: If you had done so ten or even twenty thousand times, and had then met with a case of death, you would but have received your just proportion according to recorded cases. You have no right to base your assumptions on your necessarily (relatively speaking) limited personal experience.

So, again, those who have asserted that death occurs by shock or by suffocation have usually founded their assertions either on their own observations or experiments. Here, again, it is only the record of actual occurrences which will help them. In all the questions the words of Morgagni should be recollected: "Nulla est alia pro certo cognoscendi via, nisi quamplurimas historias collectas habere et inter se comparare."

In looking over the cases in which death has occurred during the progress of chloroform-narcosis, we are able to group them so that we may throw a great deal of light on the vexed questions. We should not attempt to found on them positive conclusions; but regard the deductions from them as guides for our assistance rather than as laws. We cannot obtain the records of all the fatal cases—and the narratives of many are imperfect; our object should be rather to group similars than to obtain results from large numbers. For example, though we may found a statement as to the greater immunity possessed by women over men in death from chloroform from a large number of cases, we can discuss the question of post-mortem appearances from only a limited number; it is only in a few instances that accounts of post-mortem appearances have been given. The grouping of similars is all necessary for the employment of the numerical method.

The bulk of this volume was written before the report on Chloroform by the Committee of the Medical and Chirurgical Society appeared. This report, a monument of careful labour, gives the greatest help that can be afforded to the investigation. I had, previously to its appearance, collected the records of fifty-six cases of death from chloroform, which, with those in Dr. Snow's work, made a total of a hundred and six cases. The committee has recorded a total of a hundred and nine cases. I now propose to relate the conclusions I had previously arrived at, with the additional teaching afforded by the results of the committee. From these data, though we cannot expect to deduce *laws*, we may at least extract *lessons*.

It is a strange, and certainly a noteworthy fact, that a large proportion of the deaths occurred before the commencement of the operation for which the administration of chloroform was attempted. The following results have been recorded:

	Snow.	Scoutteten.	Kidd.
Death before commencement of operation . . .	18	22	14
„ in progress of operation .	22	6	14
„ shortly after operation .	6	12	7

The Report of the Committee* contains the following:

Stage of Anæsthesia at which Death occurred.

Commencing to inhale	10
Stage of excitement	16
Incomplete anæsthesia	24
Fully under influence	38
Ditto operation complete	14
Not stated	7
	109

Or—

Before full effect of chloroform . . .	50
During „ „ . . .	52
Not stated	7
	109

Thus it will be seen that a great many deaths occurred before insensibility was established; and very few when a profound action of the anæsthetic was sustained.

I have before mentioned how possible it is that some of the deaths ascribed to chloroform may have been due to mental shock. We cannot look back on our individual experience without recognising the possibility of sudden death occurring at such a particular time. We often hear of such taking place under the influence of emotion—of sudden joy or sudden fear. In the case of disease of the heart, which popular opinion has set down as the great bar to chloroform-

* Page 374.

administration (this being the frequent concomitant when it has proved fatal), the liability to sudden death is at its acme.

It is reasonable to suppose that fright or apprehension may have had some share in causing the mortality among those who have succumbed before the symptoms of anæsthesia have been induced—that chloroform may have been but one (and that perhaps the least) among the influences. These circumstances should urge the necessity of reassuring the patient, of calming needless irritability, and of avoiding sudden impressions of whatever kind.

Though these considerations would lead us to imagine that the death-rate is lower than it seems to be, yet the greater number of fatal cases are too evidently due to the direct influence of chloroform, and it is impossible for any one to observe the effects of its administration without being convinced of its power of compromising the vital functions. There is the incalculable boon of the removal of suffering; but there is the inevitable dread of a pause in the cycle of life. Such agents as these, capable of arresting consciousness, lead half-way on the road between life and death. Caution, therefore, would seem to be, at the very outset, all important in their employment; yet it is very certain that want of caution has had its influence in the production of the fatality. Looking over the records of fifty-six cases of death, I see that in four the chloroform was administered by the patients themselves, and in four by an unprofessional person. Is it necessary to urge the danger of the self-administration of chloroform? Nothing seems to be more obvious. The action is on a par with that of one who swallows a draught of a solution of prussic acid, hoping it will not kill him.

Though I shall presently return to the subject of the safe mode of administering chloroform, I cannot forbear citing these at the outset as facts having a direct bearing on the question of the expression of the mortality. They lead me to the conclusion that the apparent expression of the danger of chloroform as supplied by the mortality data is not the real expression; that some of the deaths recorded were influenced by terror, and that others would not have occurred had the chloroform been cautiously and fairly administered.

One of the first conclusions to which the data point is this—*that the deaths have occurred chiefly among males.* The proportion given by Snow's recorded cases is 3 males to 2 females, by

Scoutteten's 2 to 1, by Kidd's 4 to 1, by my own 2·8 to 1.* All therefore agree that men are more subject to death from chloroform than women. This cannot fail to be surprising when we consider that females have a certain monopoly of chloroform in the department of obstetrics.

Combining my own data with Dr. Snow's, I find that the average age at which death from chloroform occurs is about thirty years—more correctly 30·5 is the expression, the statement being founded on seventy-nine cases. The case at the most tender age was at five years; the chloroform being mixed with ether. A child, seven years and a half old, died at the Hôpital Ste. Eugénie in Paris. Two children died at eight years of age—one of these, operated on for squint, was unusually frightened, and it is not unlikely that in the Paris case also fear helped on the syncope. In the second case, at the age of eight, the operation was a slow one—a plastic operation. The most advanced age at which death has occurred is that at seventy-three years, recorded by Dr. Snow; though one of my cases is marked "aged." A man of sixty died in La Pitié in Paris, and a labourer of sixty-five died at the Middlesex Hospital.

The following table is taken from the report of the Committee:

The ages in the fatal cases are as follow:

Under 5 years	0
From 5 to 15 years	9
„ 15 to 30 „	30
„ 30 to 45 „	32
„ 45 to 60 „	12
Over 60 years	2
Not stated	24
	109

The next point is *the condition of the patient.* It certainly appears that the healthy and strong stand a worse chance with chloroform than those who have been debilitated by disease. As we have seen that the weaker sex has less of fatality than the stronger, so we see that those who are enfeebled suffer less from chloroform-accidents than the hale and muscular. This is so supported both by figures and by individual observation

* The numbers according to the Report of the Committee are 72 males to 37 females.

that we can scarcely refuse to receive it, as it has been entitled —the "*Law of tolerance.*"

When chloroform is given to a healthy muscular man there is frequently seen resistance to the process; there are contortions of the limbs and congestion of the face; finally, when anæsthesia is established, there is often deep coma and profound stertor. In such cases, when chloroform has proved fatal to men in the prime of life, there has either been an early resistance, and death early in the inhalation, or else a difficulty in inducing the insensibility, and a sudden change from calm to collapse. To instance the first of these modes: a man of twenty-four once died in half a minute from the commencement of the process.* So also a strong man of forty died at Bordeaux after only a few inspirations from a handkerchief; again, a cooper, forty-nine years old, died in the Bristol Infirmary early in the inhalation, the man dying, as the narrator says, as suddenly as if he had been poisoned by prussic acid.

On the other hand, in the case of a man of forty-five (occurring at Auxerre), three minutes served only to induce great muscular excitement; in five minutes more, sensibility was still unaffected; not until ten minutes had elapsed was there insensibility—then, at the commencement of the operation (which was for a tumour of the man's breast), death occurred. We shall presently see that this is the general history of the symptoms in those who have been hard drinkers.

When we give chloroform to a more debilitated patient, we see him submit to the influence calmly and quietly; the stage of excitement is short and the muscular movements are slight; he seems in a gentle sleep.

How can we account for this? By the fact that *sudden* shocks are the most prone to snap the links that bind our life together. Nature provides in disease a gradual depression of the functions: an accommodation by degrees to a less perfect life. An animal which has been gradually accustomed to breathe an impure atmosphere will continue alive though another healthy one plunged therein will die immediately. Two young Frenchwomen were poisoned by the fumes from a charcoal furnace. One, who was then in perfect health, fell senseless and suffocated; the other, who was suffering from

* Faure, 'Arch. de Med.,' 1858.

typhoid fever, resisted the poisonous influence, and screamed till assistance came. Both were rescued, but the healthy girl suffered paralysis of the left arm for six months afterwards.*

These circumstances will help to explain the fact that by far the largest proportion of deaths has occurred in cases of the most trivial operations.

The following table shows the number of deaths in the case of the several operations, and conditions for which chloroform has been administered :

Author's Table.

I. Minor Causes.		
Relief of pain.—Lead colic, neuralgia, toothache	4	
Examination of injuries or diseases . . .	7	
Minor operations.—Removal of toenail (5), of testicle (4); incisions in perineum, cauterization (11); extraction of teeth (8); fistula (5); amputation of finger (4), of toe, of penis; opening sinus; removing piles; sounding bladder; catheterism; ligature of vessels; phymosis; polypus uteri; circumcision; squint (2); removal of fæces	51	
	—	62
II. Removal of tumours (10); amputation of foot, of part of hand; of breast (2); of eyeball; perineal section: instrumental labour; plastic operations (2); removal of diseased bone (7) . .		26
III. Capital operations.—Amputation of thigh (3), of leg (2); herniotomy and lithotomy . .		7
IV. Reduction of dislocation (5); forcible extension .		6
V. Delirium tremens and mania		4
VI. Natural labour		2
		107

Table from the Report of the Committee of the Medical and Chirurgical Society :

Operations for which the Chloroform was administered in the Fatal Cases.

Amputations	16
Dislocations	5
Removal of tumours	9
Examination of injuries	3

* Lewes, ' Physiology of Common Life,' vol. i, p. 375.

Operation on male genito-urinary organs	12
„ on anus, rectum, &c.	7
„ on the uterine organs	1
„ on the eye	4
For hernia	1
Castration	4
For necrosis, excision of bone, &c.	3
Excision of joints	2
Forcible straightening of joints	3
For application of escharotics	6
Plastic operations	6
Ligature of arteries	1
Sinus in thigh	1
Impaction of fæces	1
For removal of teeth	12
Removal of toenail	5
For relief of neuralgia	2
For delirium tremens	2
For maniacal excitement	1
Not stated	2
	109

We may thus see the catholicity of this principle of "tolerance"—the feeble bear chloroform better than the strong; children are the best subjects of all; women are better than men; men are most prone to death when they are in the prime of life; and when they are debilitated by pre-existing disease, their chance is better than when they submit to chloroform for trivial causes in more perfect health and strength; and, further, the chance of ultimate recovery is greater when an operation is done under chloroform for a diseased condition, than when it is undertaken for an injury.*

It has been urged that one reason to account for the danger in cases of removal of toenails, of operations upon the perinæum, &c., is the deep narcotism required to be induced: sensibility lingering long in these structures. To estimate rightly the value of the proposition, it will be well for us to consider the relation between the cause for which chloroform-narcotism has been induced, the quantity that has been administered, and the symptoms that have been induced. The quantity can only be arrived at approximately, and, as will presently be shown in the prevalent mode of chloroform-administration, the admixture with air is wholly indeterminate.

* See p. 15.

It has been before shown that the deaths from chloroform do not usually take place from its profound action, but at an early stage, when it has not even completed the abolition of sensibility. This is a first objection to the notion of deep narcotism causing the fatality in these operations. Next, as to the *quantity which has been administered* in cases in which death has occurred. It is undoubtedly true that the great proportion of deaths has been in cases wherein but little chloroform has been inspired. "In one instance in which only thirty drops had been inhaled in vapour, the patient died in one minute, and in another so small a quantity as fifteen or twenty drops proved speedily fatal."* In five cases that I have collected, the amount used has been half a drachm or less; and in five more the quantity has not been stated, but it has been said to have been "very small." The average amount employed, taking thirty-six cases, was 1·7 drachms. In three cases, not included in the estimation, the amount used was an ounce and upwards. In the first of these (wherein an ounce was employed), the symptoms illustrate the mode I have before mentioned, in which chloroform acts with the strong and healthy. A labouring man long resisted the influence, then fell into a state of deep and sudden coma.† In the second case (a lady), the patient seems to have died from deep narcotism—10½ drachms were employed.‡ In the third case, occurring in Edinburgh, the man was very robust.§ On the other hand, very large quantities of chloroform have been employed without the induction of any signs of danger. Thus, in a case of tetanus, occurring at Guy's Hospital, more than a pint was used in twenty-four hours.

We will next inquire whether in those cases of toenail removal, operations upon the perinæum, reduction of dislocation, &c., deep narcotism was induced, and the patient *did* succumb to a profound action of the vapour. A partial answer is at once given on a cursory review of Dr. Snow's cases. By far the greater number of deaths were in "intended operations," that is to say, narcotism had not been induced sufficiently to allow the performance of the operation. In two cases only of removal of toenails was the operation completed. The first (case 12, Dr. Snow) followed the course I have so often mentioned in

* 'Table of Fatal Cases,' by Dr. Warren, U.S., p. 23.
† Snow, p. 142. ‡ *Loc. cit.*, p. 158. § *Loc. cit.*, p. 166.

the case of strong men; long excitability—rapid collapse; the second, of which the details are meager, occurred to a physician, aged twenty-seven.* In only one of the cases of fistula was the operation completed; but a case in which an operation for piles was performed, the patient succumbed to the profound action. In three of the cases of reduction of dislocations there was evidence of profound action. That one of the causes of death from chloroform is the deep narcotism required for certain operations is undoubted: but it will be seen that this is far from being the only or even the principal cause. In by far the greater number of cases there has been an intolerance of the chloroform. At the first, the symptoms of narcosis have not been perfectly induced, and death has occurred before the operation has been performed.

There are two modes of death from chloroform—the first, and most frequent, sudden death at the early stage of its influence; the second, a gradual mode,—the comatose state, induced on account of the deep insensibility or perfect muscular relaxation required for the performance of the operation, ending in extinction of life.

CHAPTER VIII.

DISEASED CONDITIONS WHICH INCREASE THE DANGER OF CHLOROFORM.

Of all conditions of system, probably the worst to bear chloroform is Alcoholism.

Experience in cases of *delirium tremens* is sufficient to forbid its use. The expression of its danger is inadequately represented in the published records: Dr. Kidd has collected nine cases of death wherein chloroform has been administered to calm the agitation of delirium tremens. The modes of death

* 'Lancet,' 1860.

in these cases are twofold—thus, in two cases, death has been very early and very sudden; one is said to have occurred after three inspirations from chloroform sprinkled on lint; another happened at Bordeaux after a very few inspirations. The other mode of death is collapse after violent muscular excitement.

It is a most noteworthy fact that, when we look over the records of death from chloroform, we find that very many have occurred in *hard drinkers*. Intemperance induces a state of system most inimical to chloroform. Of the cases I have collected, eight were in men accustomed to drink freely, exclusively of three cases of delirium tremens. An analysis of the cases shows also that deaths are frequent in persons of that class of life whose habits are those of intemperance. Thus death occurred in no less than six sailors, three soldiers, three labourers, a cooper, a cattle dealer, a miner, &c., &c., and taking into consideration the general history of the cases, the sequence of the symptoms, and the individual history of each, I have no doubt that intemperance led to the fatal issue in many instances wherein it is not directly recorded. I have mentioned the suddenness of death in delirium tremens. In subjects of intemperate habits I have observed the second mode of sequence of symptoms occur: it is an aggravation of the effects observed in the strong and muscular—a great primary resistance, prolonged muscular agitation, hyperæsthesia rather than anæsthesia, violent endeavours to assume the erect posture and after a considerable time, sudden change to deep insensibility, clammy perspiration, complete relaxation, snoring respiration, and feeble pulse. This is the almost constant history: so that I always feel anxiety in dealing with these cases. The careful administration of a gradually increasing proportion I have found to be the safest plan, and the avoidance of the rapid and forcible inhalation which the patients usually attempt. Moreover, I am careful to diminish the proportion just as the symptoms of the muscular stage are becoming less under the control of the will, knowing that the chloroform left in the lungs and in the blood will take a greater time to manifest its effects in these cases, and that the residual proportion will produce a profound effect after the continuous inhalation is suspended.

It is to be borne in mind also that habits of intemperance

lead to the production of fatty degeneration of the muscular structure of the heart—a condition which we shall presently speak of as, per se, a bar to chloroform administration. Hence it is very probable that though the direct fatal effect may have been due, in many cases of this form of heart disease, to the imperfection of the muscular fibre, yet the remote cause may have been a habit which has predisposed to it. Alcohol may have had to answer for a part of the oppugnancy to chloroform which has been ascribed so universally to disease of the heart.

In certain *poisoned conditions of the blood* the use of chloroform is fraught with danger. Such are uræmia and pyæmia in the stage wherein they influence the mental functions. I consider that chloroform should not be administered when there is delirium, except it be in the case of epilepsy. But in cases of poverty of the blood (anæmia or spanæmia), chloroform acts most benignantly.

In *shock to the nervous system*, as in the first influence of severe accidents, chloroform should be withheld.

In *hysteria* and *nervousness* more than usual care should be used in the administration of chloroform; though there is no approach to the danger of the class of cases first mentioned. The influence of fear or terror is, however, very potent, and every means to diminish it should be adopted. In these cases I believe it to be most important to commence with an atmosphere of so complete a dilution that the patient shall not suffer the least inconvenience. Accommodation to the smell, taste, and mode of influence of chloroform is to be attained, and then a gradually increasing proportion administered. I shall have to speak more of this hereafter. In hysteria, one should be careful to intermit the inhalation now and then when a very deep inspiration occurs (as it frequently does).

The average age at which death has occurred in women is 30·2—almost the same as that in the case of men: the married are almost twice the number of the single. Of course these observations do not go to prove much, but they tend to show that the element of hysteria has not had much to do with the fatality, whereas the general history indicates that nervousness has had a great deal. On the other hand, there were six deaths at the age 15—17, and in these, hysterical symptoms have not been indicated in the histories. In young unmarried girls, where there have been fatal symptoms, they have been very sudden—*sidé-*

ration, as the French say. The first case which occurred under chloroform* was an instance of this.

Organic diseases present, *à priori*, no bar to the administration of chloroform. It has been shown how that the debility which they induce is rather favorable to the anæsthetic action than otherwise.

In *disease of the lung*, the action is usually remedial, rarely toxic; but there are instances wherein a direct asphyxia has taken place from chloroform acting upon an extensively diseased lung. An example is recorded in the 'Medico-Chirurgical Review' for October, 1858. A soldier was placed under chloroform for removal of the testis—after some strong muscular contraction he gave a violent expiration; then the pupils dilated, and all signs of suffocation occurred. On post-mortem examination, the lungs were found to be highly congested; and it was discovered that the man had suffered from miliary tubercle. These tubercles studded all the lungs, and there was a cavity in addition. On the other hand, patients suffering from consumption are, as a general rule, among the very best to submit to chloroform. I consider the state of the case to be thus: if a patient is suffering from chronic disease of the lung, whether consumption, or emphysema, or bronchitis (provided there be no evidence of recent congestion), there is no special danger in the administration of chloroform. But if there is a general congestion, an acute hyperæmia of the lung, chloroform should be withheld.

Disease of the heart. This is the bugbear of those who are advised to submit to chloroform. Very rarely but we are asked by the patient if we are quite sure that his heart is not diseased, and that it will allow him to bear chloroform with impunity. This feeling has been fostered in a variety of ways, and I believe has done more harm than good by nurturing an unwholesome terror of chloroform. How many have passed through life without having, or thinking they have had, something wrong about their heart? The daily practice of each of us will tell how deeply implanted is the idea. Almost every patient who comes, points to his or her heart as the "fons et origo mali," whatever may be the matter; and so oftentimes is the organ blamed for errors not its own. A calm dispassionate examination of the influence which heart disease

* Dr. Snow, case 1.

has effected upon the danger of chloroform, will dissipate much of this terrorism, though of course it will only go to strengthen the dictum that in a *certain condition* of the heart, chloroform exerts an influence unusually baneful.

The following table shows the appearances of the heart in fifty-six cases in which post-mortems have been performed:

Substance of the heart pale, soft, and flabby . . .	14
Heart loaded with external fat	1
In one of the first-mentioned cases also there was an extensive deposit of external fat.	
Fatty degeneration of the heart	18
Valvular disease	2
In one case also co-existent with fatty degeneration.	
Heart normal	21
	56

A first glance at this table will enable us to form a more correct estimation of the danger of chloroform in cases of heart disease. It is very rarely indeed that valvular disease of the heart has had anything to do with the induction of symptoms of danger. Over and over again I have given chloroform to patients affected with incompetency of the valves of the heart, and I have found them very good subjects indeed for its influence. This eliminates a very large proportion from the ban which attaches to chloroform in heart disease. In persons affected with valvular disease—in those in whom cardiac mischief is the result of acute rheumatism, for example—there is no special danger in the administration of chloroform.

The danger, therefore, is in those in whom there is incompetence of the heart's fibre, and the table shows this danger to be great. We know from observed facts that the heart stands the worst chance of all the organs which keep up the processes of life in the case of chloroform-narcotism. In it first circulates the altered blood, and from it are taken those mental influences which, in a normal state, contribute to its stimulus; and it is seen that in the case of man the heart is usually the first to succumb to the over-influence of chloroform. When its fibre is imperfect, therefore, it may be well understood that there is a condition of danger.

It is noted in the table that fourteen cases showed a certain

amount of flabbiness, &c., of the heart structure. Much importance cannot be attached to this expression. In the post-mortem room it is very rarely that we find a case in which there is a perfect condition of the heart-muscles; especially in our ill-nourished hospital patients we find this imperfection. Hence the question is seen to be not positive, but relative. In these cases, as in those wherein there has been actual transformation of the muscular fibre, we can lay down no positive rules, as the disease does not always give us positive signs.

In nearly all the cases wherein chloroform has caused death in persons suffering from fatty degeneration of the heart there has been a difficulty in inducing the symptoms of anæsthesia; in all but two the abolition of sensibility was unaccomplished; death was usually very early and very rapid; frequently there was a sudden lapse to deep stupor, and in many cases great muscular agitation, occasionally assuming an epileptiform character.

The general lesson inculcated would seem to be this: that in cases of marked fatty degeneration of the heart, chloroform should not be administered; that in cases wherein a debility of the heart is suspected, unusual care should be exercised to administer a free dilution, so that the heart should not be paralysed by the sudden shock of an influence which it cannot withstand.

What are the principles of diagnosis? Of the first class, viz., fatty degeneration, the following are the most important points. The previous history of tendency to faintings; the occurrence of occasional dyspnœa from congestion of the lungs; the indication of atheroma of the arteries; feebleness, and especially *intermission* of the pulse; the impulse of the heart found on stethoscopic examination to be feeble in proportion to its size; the countenance showing a certain yellowness of hue, and a congested state of the capillary vessels of the cheeks; the occurrence of arcus senilis. If the occurrence of these signs should give rise to the diagnosis that there is fatty degeneration of the heart, we are not justified in giving chloroform.

If, with other indications of a satisfactory state of system, there is yet evidence of debility of the heart, chloroform should be administered gradually and slowly, and freely-diluted, and then the danger in these cases is almost abolished.

The question of responsibility in these cases is difficult; it is so much relative, so little positive. The broad rules that I have laid down I believe to be sufficiently practical.

CHAPTER IX.

THE DANGER OF THE INCAUTIOUS ADMINISTRATION OF CHLOROFORM.

We have seen that the indiscriminate administration is dangerous; that very intemperate persons and those suffering from one of the forms of heart-disease are especially prone to suffer the accidents of chloroform-administration; and that in many other conditions a great amount of care should be used in conducting the inhalation. We now come to consider the usual means employed in the exhibition of this most powerful agent.

The usual practice is to administer chloroform from a towel, napkin, or some porous material which will absorb it, and readily allow its vapour to be given off near the nose and mouth of the patient about to inhale it.

The great point which established the universal employment of chloroform was its property of volatility. It evaporated rapidly at all temperatures of the air; it wanted no complicated apparatus to cause its diffusion and render it respirable; a teaspoonful or so poured on a pocket-handkerchief and held near the mouth and nose served every purpose for producing insensibility. No harm seemed to accrue from this; and as "familiarity breeds contempt," so the methods of administration became careless and slovenly. There have been occasions in which a worsted glove, a nightcap—anything, in fact, which would absorb chloroform—has been used as a wherewithal to administer its vapour.

When fatal cases had occurred from the inhalation, and when science had contributed to a more exact appreciation of the properties of the anæsthetic, a reconsideration became

necessary of the means which should be employed in the administration.

The first mechanical means which were employed, however, were rather constructed for convenience in the administration than for any principle of safety. They seemed to be intended to prevent the waste of chloroform, which occurred in the other method. Thus glass globes, provided with valves, metal masks covering the face, and similar contrivances, were used, which rather prevented than encouraged free dilution with air. So that, on looking over Dr. Snow's record of fatal cases, we frequently see it stated that an "Inhaler" was employed, yet we find that such inhaler did not provide for a free admixture with atmospheric air.

Dr. Snow, whose large experience and whose indefatigable devotion to the investigation of the subject gave him the greatest opportunity of arriving at a just conclusion, strongly urged the necessity of securing a sufficient and definite dilution with air. He invented an instrument by which this might be accomplished. His arguments could not fail to convince a large number; but there are yet many who prefer the "ready method," who seeing no danger in their own practice, almost disbelieve in the possibility of danger, and who discourage the use of mechanical means for dilution as so many stumbling-blocks in the way.

The great objection to the administration of chloroform on a handkerchief is its irregularity—the utter ignorance we have of the strength of the vapour inhaled at a given time. At one moment a quantity of air strongly impregnated with chloroform may enter the lungs; at another, a breath may be taken of almost pure atmospheric air. We know that twenty-four minims of chloroform, if breathed without any waste, is sufficient to produce and sustain anæsthesia for a prolonged operation —nevertheless, when chloroform is given upon a handkerchief, &c., it is usual to commence with two or three drachms, and to add more from time to time as circumstances may require. Thus in the course of an operation, two or three ounces are frequently used. Obviously there are no data on which to found a statement of the strength of the vapour inhaled at a given time; but at a temperature of 60° (an ordinary temperature of the atmosphere), air can take up twelve per cent. of chloroform vapour, a quantity sufficient to produce danger or death.

In the records of fatal cases, very frequently the exact means employed for the administration are not indicated, but the use of handkerchief or napkin is so general, and so much presupposed that, in those wherein it is not precisely stated to the contrary, we may nearly always conclude that this "ready method" has been adopted.

Table from the Report of the Chloroform-Committee:

Mode of Inhalation.

On handkerchief, towel, or lint	55
Lint with sponge	5
On sponge	7
With the ether-inhaler	2
Snow's inhaler	5
An inhaler	21
Not stated	14
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Dr. Anstie* gives an account of twenty-one cases in which he saw symptoms of danger in the course of chloroform-administration. In 858 cases, chloroform was given on lint or by some such means—of these, 16 showed signs of danger. In 2200 cases, an inhaler was employed—and of these only five showed dangerous symptoms. Hence, while in the first instance the proportions of those evincing danger to the whole number who inhaled was about *one to fifty-three*, in the cases wherein due dilution was provided for, the proportion was only *one to four hundred and forty*. This seems to be significant enough; but the significance is increased on further examination; for in all the five cases there was either a defective arrangement of the apparatus, or the inhalation was inadvertently carried too far; or the administration, though commenced with the inhaler, was continued with merely lint as the medium.

The great argument which we have to answer—which is put forward in every conversation concerning chloroform—which crops up in every letter to the 'Times' upon the subject, is the argument derived from personal confidence. "I have given chloroform two or three thousand times," a gentleman has said to me, "and have never had a case of death." The inference is supposed to be: "The method I employ is the

* 'Stimulants and Narcotics,' p. 378.

proper one for the administration of chloroform;" but the premises do not justify this, and the objection is: "you may give chloroform ten or even twenty thousand times, and then meeting with a fatal case you will only have achieved your just proportion according to the numerical records." A man may pound gunpowder in a metallic mortar for a lifetime and never suffer from an explosion; but the inference from accumulated facts is, that it is dangerous to pound gunpowder in a metallic mortar. The experience of one individual is not sufficient to establish a right plan of action in either case—recorded facts and collected experiences afford the only proper material for generalisation.

Dr. Snow's* experiments showed that three grains of chloroform to each 100 cubic inches of air (about 2·3 per cent.) was the proportion which could arrest the breathing of warm-blooded animals. He considered it dangerous for the human subject to breathe more than five per cent. of the vapour. Messrs. Lallemand, Perrin, and Duroy, find that though mammifers can remain in an atmosphere containing four per cent. of chloroform-vapour for a considerable time, they die rapidly in an atmosphere containing eight per cent. There is no doubt, therefore, that insufficient dilution is fatal; yet we know that from a handkerchief one may breathe a proportion of twelve per cent.; the danger is thus seen to be obvious.

It has been said that the objection to the use of the handkerchief is overcome if it be employed by a practitioner who is accustomed to this mode, and who is zealous to interpret signs of danger. No signs of danger, it is answered, will indicate the strength of the inhaled atmosphere, and the anæsthetic state should be kept in bounds by no such marks as these. In time past, the accidents from chloroform were ascribed to a peculiarity in the patient's constitution inimical to it—to idiosyncrasy. Idiosyncrasy is but a word, a towel or napkin is a fact. It is time that we emerged from the obscurity of this expression, which, after all, is but a cloak for ignorance. What is the idiosyncrasy inimical to chloroform? The previous pages will have shown that it may be the result of causes engendered by disease or intemperance —or it may be a state of particular emotion, a tendency to faintness or fear—or it may be explained by the unsatisfactory

* 'On Anæsthetics,' p. 70.

mode in which the agent is applied. Let these matters be stated, but do not let the accidents of chloroform be hidden over by a Greek word signifying nothing.

I can hardly be accused of inveighing too strongly against any lax method of chloroform administration, whilst the records of fatal cases point the lesson they do. Witness the number of deaths which have occurred during the self-administration of it.* At one time it is said to have been taken "disguised with perfumes" by the patient; at another, it is recorded as "given by an unprofessional person on lint rolled up in the hand." Dentists have administered it without other help for the performance of their operations, and have been horrified to find that death has occurred; and patients suffering from toothache have by its means committed accidental suicide.

The trumpet of the Medical and Chirurgical Committee has, I consider, on this particular point—the safe administration of chloroform—given forth an uncertain sound. These premises which they give are logical enough:

"The several effects produced by the administration of chloroform, as well as of other anæsthetics, are tolerably uniform if the same strength of vapour be employed; and there is much reason to suppose that the irregularities attributed to it have been, in a great measure, due to the uncertain degree of its concentration. Experiments upon the lower animals, however, equally with observations on man, prove that there is but a narrow limit between that strength in which the vapour may be safely inhaled, and that which is likely to produce alarming symptoms, if not death. But whether the hazard originates in natural or in accidental causes, the conclusion must be the same—that it is extremely desirable to adopt a method of administration by which the quantity of the vapour actually being inhaled may be graduated.

"The results of the experiments which have been detailed, show that it is as desirable to measure accurately the strength of the vapour as to weigh the dose of a medicinal agent administered by the mouth."

Such opinions must be shared by all who have thought deeply on the subject. But then comes the lame and impotent conclusion. The method of administering the anæsthetic on

* See p. 66.

a handkerchief or lint, "ensures a sufficient mixture of atmospheric air with the vapour; and if the handkerchief be held at a proper distance (one and a half inches from the mouth), there is but little fear of the air becoming impregnated with a dangerous proportion of vapour."

I consider that this last paragraph is decidedly opposed to the teaching of the preceding ones, as well as to the considerations which I have put forward in this chapter.

Chloroform should never be administered except by a qualified practitioner, and never without the safeguard of perfect dilution. "Under no circumstances is it advisable for a person to give chloroform to himself."* If possible, the services of one accustomed to the administration of it should be secured. Some of our hospitals have appointed a chloroformist: it would be well if all followed that example. Too often one has seen the important office delegated to a dresser or inexperienced student.

I consider that due mechanical means for the dilution of chloroform-vapour is an imperative necessity; and in support of this opinion I revert to the following considerations:

1. In all cases of experiments upon animals the symptoms have been induced in the most regular, uniform, and safe manner, when a fully diluted vapour has been administered.

2. In our experiments upon the condition of the circulation in narcosis,† we have always found highly charged atmospheres cause great trouble of the capillary circulation; whilst diluted atmospheres have, as it were, allowed the gradual accommodation of the system to the new state.

3. Experiments have taught us that a too high proportion—*i. e.* 5—8 per cent., is fatal to animal life.

4. In the case of strong atmospheres the danger is due, not only to the quantity of chloroform present, but to the rapid and sudden influence produced.

"Lorsq'une dose notable de chloroforme est absorbée tout d'un coup, le système nerveux, surpris en quelque sorte par l'action excessive du poison, est subitement opprimé, et ses fonctions se trouvent presque immédiatement anéanties."‡

5. We know by practical experience that an atmosphere

* Abstract of Report of the Chloroform Committee of the Royal Medical and Chirurgical Society.

† See p. 61.

‡ Lallemand, Perrin, and Duroy, 'Du Rôle, &c.,' p. 358.

strong in chloroform-vapour, causes, in the human subject, phenomena of resistance and the most apparent signs of danger.

6. We find that a comparatively small proportion of danger has resulted when proper means for dilution have been employed.

7. From personal experience, comparing the general ease of the process when an inhaler is used with its course when a handkerchief or lint is employed, one cannot fail to prefer the former, for conducing to the quiet onset of the symptoms, the comfort of the patient during the inhalation, and the mitigation of the after-effects.

What proportion of chloroform-vapour, if this proportion be continued throughout the whole inhalation, is it most safe to inhale?

Dr. Snow considered that about five per cent. could be inhaled; but experiments have shown that in animals safety is greatest in atmospheres of two to four per cent. Dr. Anstie considers three and a half per cent. the proper proportion. The Chloroform Committee give three and a half as the average amount, and four and a half as the maximum which can be required.

I consider that for a continuous inhalation of a definite proportion, three and a half per cent. is the dilution which ought to be inhaled. This ratio should be sustained by mechanical means, and by no guess-work contrivances.

Another circumstance now comes before our consideration—*the tolerance of chloroform.* If we commence with very small proportions of chloroform, and gradually increase the quantity, we find that the system gradually accommodates itself to the influence, there is no discomfort or terror at the outset, there is no resistance, and the phenomena assimilate to those of natural sleep. According to the experiments of M. Claude Bernard, animals gradually accustomed to vitiated air, will live in an atmosphere that is instant death to a healthy animal. Thus, "a sparrow left in a bell-glass to breathe over and over again the same air will live in it for upwards of three hours, but at the close of the second hour—when there is consequently still air of sufficient purity to permit of *this* sparrow breathing it for more than an hour longer—if a fresh and vigorous sparrow be introduced it will expire immediately."* The same is true of chloroform; if the system be

* See Lewes, 'Physiology of Common Life,' vol. i, p. 374.

gradually accustomed to it, it will bear a larger dose. Under this head the following points offer themselves for consideration:

1. We find that the maximum of danger obtains in the early stages of the inhalation.* It is then that are seen, as it were, a repudiation of the vapour, a resistance at the outset. Reflex action of the glottis endeavours to prevent the entrance of the vapour to the lungs, coughing or choking are produced—the patient makes voluntary efforts to escape the vapour—and the records show that sudden death has thus occurred.

2. But it is seen that at a later stage of the inhalation, a proportion is breathed with ease, which at the commencement would induce all the signs of resistance.

3. In our experiments on frogs, we have found that when we have proceeded from a dilute to a concentrated atmosphere, the circulation has been carried on with far less irregularity then, when the concentrated atmosphere has been breathed at the first.

4. In the human subject I have found that, if the inhalation be commenced with so small a proportion of chloroform that the patient can recognise in it nothing unpleasant, and if this proportion be, by mechanical means, very gradually increased, there is the most perfect absence of signs of danger and of muscular excitement.

I am quite sure that the danger of chloroform is not proportionate to the quantity retained in the system—it is its early influence, the "brusquerie" of its action which has caused the great part of the fatality.† It is not only at the early stages of inhalation, but in cases where the smallest quantities have been used, that cases have been rendered suddenly fatal. A little patience, a little mechanical help to ensure the most perfect dilution, and a regular and gradual increase of the proportion inhaled, and the greatest part of the danger of chloroform is taken away.

To sum up, therefore, I recognise two principles for attaining the maximum of safety in chloroform-administration.

* See p. 65.

† "The truth is, however, that if there be too much vapour of chloroform in the air the patient breathes, it may cause sudden death, even without previous insensibility, and whilst the blood in the lungs is of a florid colour."—Snow, 'On Anæsthetics,' p. 79.

I. The continuous inhalation of an atmosphere of known strength—an atmosphere of about three and a half per cent. We may call this the principle of definite dilution.

II. The administration of an extremely dilute atmosphere at first, and the progressive increase in its strength, never overpassing five per cent. We may call this the principle of tolerance.

The modes of putting these principles into practice will be discussed in a future chapter.

CHAPTER X.

SIGNS OF DANGER UNDER THE INFLUENCE OF CHLOROFORM.

In those cases in which sufficient details are given, the signs of danger which have appeared in the course of chloroform-narcosis have presented a relative frequency which is indicated by the following table:

Cessation of pulse	19
Concurrent signs, muscular contortion, vomiting, relaxation of sphincters (in two cases only the pulse showed signs of failure before actually stopping).	
Pallor of face and lips	11
Cessation of hæmorrhage from wound	2
Vomiting followed by immediate death	2
Muscular excitement	15
Starting. endeavour to rise up, opisthotonos, epileptiform convulsion, trismus, in many cases accompanied by lividity of countenance.	
Embarrassed respiration	13
Laboured, irregular, or profoundly stertorous.	
Cessation of pulse and respiration simultaneously . .	2

Dr. Anstie relates the following cases in which alarming symptoms occurred out of a total of 3058 administrations.*

* 'Stimulants and Narcotics,' pp. 378, 379.

	Subject.	Nature of operation.	Period of occurrence of symptoms.	Nature of symptoms.	Duration of symptoms.	Mode of administration.
1	Child, æt. 2	Circumcision	Three minutes from commencement of inhalation	Weak, fluttering pulse; gasping respiration; great pallor. Sudden	15 minutes	On a handkerchief.
2	Child, æt. 6 months	Harelip	Two or three minutes from commencement of inhalation	Flickering, unrhythmical pulse; gasping breathing; livid lips. Sudden	10 minutes	On a sponge.
3	Man, æt. 40	Hæmorrhoids	End of operation; on a second application after partial recovery	Sudden arrest of pulse and breathing; livid lips; jaw dropped	25 minutes	Snow's inhaler. Artificial respiration.
4	Lady, æt. 52	Amputation for cancer of breast	Middle of the operation; but little blood lost	Sudden intermittence of pulse; great pallor	5 minutes	On a handkerchief.
5	Lady, æt. 32	Varicose aneurism of lip and cheek	Less than half a minute from the commencement of inhalation	Sudden intermittence of pulse; pallor; laboured respiration	10 minutes	On a sponge.
6	Man, æt. 60	Hæmorrhoids	Near the end of the operation	Sudden pallor; flickering, running pulse	7 or 8 minutes	Snow's inhaler, then on lint.
7	Girl, æt. ?	Removal of lower jaw	Three and a half minutes after commencement. One minute after induction of full anæsthesia	Sudden flickering of pulse; slow and gasping respiration; great pallor	5 minutes	On lint. Rapid anæsthesia.

	Subject.	Nature of operation.	Period of occurrence of symptoms.	Nature of symptoms.	Duration of symptoms.	Mode of administration.
8	Girl, æt. 19	Plastic operation on face	After a very few deep inhalations	Sudden pallor; livid protruded tongue; slow, gasping respiration	5 or 6 minutes	On lint.
9	Man, æt. 38	Radical cure of hernia	Middle of the operation	Sudden pallor; very hurried, weak pulse (no large hæmorrhage)	A few minutes (very sick for some hours)	In Snow's inhaler, afterwards on lint.
10	Man, æt. 40	Lithotomy	Two minutes from the beginning of inhalation	Irregular weak pulse; deadly pallor	12 minutes	On lint.
11	Man, æt. 22	Amputation of forearm	After a few inspirations	Sudden insensibility; pallor; failure of pulse	10 minutes	On lint.
12	Man, æt. 43	Fatty tumour removed from shoulder	Inhalation continued for six minutes	Extreme dilatation of pupils; stertorous, gasping breathing; pulse pretty regular	4 minutes	In Snow's inhaler.
13	Man, æt. 31	Circumcision	Middle of operation	Sudden pallor and failure of pulse, then of respiration	6 minutes	On lint, two additional doses.
14	Woman, æt. 29	Removal of scirrhous breast	After a few inspirations	Extreme pallor; intermittent pulse	5 minutes	On lint.

15	Girl, æt. 22	Necrosis	After a few inspirations	Faintness; hurried respiration	3 minutes	On lint.
16	Boy, æt. 15	Lithotomy	One minute from formation of complete anæsthesia	Sudden pallor and failure of pulse	5 minutes	On lint.
17	Woman, æt. 32	Plastic operation on perinæum	One minute and a half from commencement of inhalation	Simultaneous failure of pulse and breathing; jaw fallen	20 minutes (artificial respiration)	On lint.
18	Man, æt. 56	Perineal section	Just after formation of anæsthesia	Sudden pallor; failure of pulse; livid lips; gasping respiration	15 minutes	On lint.
19	Woman, æt. 42	Removal of scirrhous breast	Sudden and violent epileptiform convulsion at end of first minute of inhalation	Pallor; pulse very weak after fit	8 minutes	Weiss's inhaler (out of order).
20	Woman, æt. 37	Removal of breast	Two minutes from commencement of inhalation	Sudden pallor; failure of pulse; respiration gasping	3 or 4 minutes	On lint.
21	Man, æt. 21	Evulsion of toe-nail	Middle of operation	Sudden pallor; gasping respiration; fluttering pulse	20 minutes	On lint. Artificial respiration.

The following are the deductions of the Chloroform Committee of the Medical and Chirurgical Society:

Mode of death assigned.

Syncope	56
Syncope during stage of excitement	6
Died suddenly	6
Died in a fit	10
Pulse and respiration ceased together	9
Failure of respiration (pulse not noted)	6
Failure of respiration (pulse remaining)	2
Not stated	14
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In our consideration of these signs it will be well to divide them into four classes.

I. Signs of sudden cessation of the heart's action. These seem to be the most frequent of all the indications. The administrator having his finger on the pulse of the patient finds it suddenly stop; or, as has happened in a few instances, he may find it first flicker and then stop; the state is one of induced faintness. Or while the patient is apparently satisfactorily under the influence, a sudden pallor of the face and lips is observed, and efforts to restore the circulation are of no avail.

In these cases there is seen to be no embarrassment of respiration. It often continues after the pulse has ceased, then gradually subsides. It is quite clear that these are not signs of suffocation; they are symptoms of palsy of the heart.

They may be uncomplicated, or the following conditions may coexist:—(1) A convulsive action of the muscular system, or (2) vomiting, or (3) relaxation of the sphincters.

In the records of many, it appears that there suddenly occurred "deadly pallor and cessation of the pulse."

In others, just at the stage of muscular contraction, the pulse ceased. This muscular excitement consists of spasmodic rigidity of the principal flexor muscles. These instances are separated from those in which the muscular agitation was the primary sign of danger, which will be considered under the next head.

The coincidence of failure of the pulse with vomiting is a point of extreme importance. In two cases, the occurrence of

vomiting was the only sign of danger—in several cases it has immediately preceded the fatal signs. Vomiting represents a state of considerable nervous depression. Whenever I have observed it in cases of chloroform-narcotism it has been accompanied with quasi-epileptic signs. There has always been loud grinding of the teeth. Its very occurrence is evidence of an attempt, on the part of nature, at elimination. My advice is, if vomiting occur in the course of chloroform-narcotism, suspend the inhalation and encourage the effort. Tickle the fauces and empty the stomach as much as possible. It is not that the act of vomiting causes depression—rather it is the indication of a preinduced depression. If there be a possibility give a little wine or brandy and water, and then continue the inhalation. Prevention is better than cure, and the imperative necessity that the stomach should be free from any considerable amount of food should be strongly urged. I have always found a little brandy and water, or a glass of wine, given before the inhalation, beneficial, and I believe it diminishes the tendency to vomiting.

According to the observations of Lallemand, Perrin, and Duroy,* upon animals, vomiting and involuntary expulsion of fæces may occur, at two periods of the anæsthetic action. First, in the period of excitation (as most frequently in dogs). Secondly, (as in reptiles and birds) in the period of muscular resolution. They observe this most important point, "We have usually experimented only on fasting animals; but once we happened to give chloroform to a dog whilst it was digesting a full meal, the animal having escaped our observation. The course of the phenomena was so irregular and so grave that we considered it our duty to record the experiment, in order to show how important it is in surgical practice only to administer chloroform when the stomach is empty. In all experiments wherein the dogs were fasting the march of etherism was regular. We may, therefore, attribute to the state of digestion, the unusual phenomena which complicated the process as well as the rapid occurrence of the fatal accidents which terminated it. To elucidate this point we submitted to inhalation three dogs a short time after they had taken food, but the results were incomplete. The animals betrayed a painful anxiety, and rejected the food which loaded the

* 'Du Rôle,' &c., p. 292.

stomach; the vomiting relieved them, and the etherisation resumed its ordinary course."

If vomiting occur *a short time after* the cessation of the pulse, it is generally a prelude to a reaction from the state of syncope. It is a favorable sign.

Relaxation of the sphincters is evidence of an influence even more profound than that which gives rise to vomiting. Its occurrence is of the gravest import; in several cases it has immediately followed stoppage of the pulse.

II. *Signs of muscular excitement.*—These may be voluntary or involuntary. When voluntary they have occurred early in the inhalation—the patient has struggled with his hands and feet; has stiffened and risen up from his recumbent position, and has fallen back dead. Or, as in the case of hard-drinkers, the struggling and resistance have been prolonged, consciousness has been long unobliterated, the violent muscular contortions have suddenly subsided into collapse, and the patient has died.

When involuntary, the signs have usually occurred just at the time when insensibility has been becoming perfect. The spasm has, in some instances, consisted in violent contractions of the flexors; in others there have been clonic convulsions. In these latter, lividity of the face has been a sign, caused by the suspension of the action of the muscles of respiration. Occasionally the spasm has assumed the character of an epileptic convulsion. In other instances there has been tonic spasm; trismus and opisthotonos have been observed.

III. *Signs of embarrassed respiration.*—These are not so frequent as might be imagined. Still it is of the utmost importance that a full attention should be paid to the state of the breathing. In the administration of chloroform no indication should be disregarded; the administrator should keep a constant watch over the pulse, and, at the same time, he should carefully note the condition of the respiration. We see that a watchful attention to the pulse is most necessary at the earlier stages of the action—it is then that the accident of syncope is most frequent. At the latter stage, embarrassed respiration becomes a sign; and this is an index of the profoundity of the action. Stertor always indicates a profound influence.

The character of the respiration which has indicated danger and has ended in death, has been—(1) laborious inspiration, (2) irregular breathing, (3) stertor.

It is strange that in all of those cases but one in which the first signs were embarrassment of breathing (in which, in fact, the symptoms were those of asphyxia) the patients were hard drinkers. The only exception was a case in which symptoms of asphyxia were induced by the existence of very extensive disease of the lungs.

In these cases the symptoms were due to one of two causes —over-narcotism of the nervous centres; such being the cases which died with the symptoms of coma—or direct asphyxia.

We have seen heretofore that the history of all is, that the heart's action ceased before the breathing; that, in fact, death was due to syncope, *i. e.* paralysis of the heart: and those cases which assumed the lividity characteristic of suffocation, were in reality only the manifestation of a spasmodic action of the muscles of respiration. The signs of primary failure of the heart separated them from the catalogue of true asphyxia.

That chloroform is capable of primarily arresting respiration, and causing death by asphyxia is, however, proved by the minority of cases. In only one case of the fifty recorded by Dr. Snow, were the symptoms those of asphyxia.* Other cases have since occurred; for instance, the case of the French soldier before mentioned. In this instance, after the patient had been inhaling for two minutes, and had evidenced great resistance and strong muscular contraction, he started up, gave one strong expiration, the pupils dilated, and the appearance became that of suffocation. All the witnesses ascribed death to asphyxia.† In another case occurring to an inveterate drinker; during twelve minutes he manifested great excitement, the face became congested and the breathing laborious, the whole venous system became turgid, and then respiration ceased before the pulse.‡ Similar symptoms, also occupying an equal time, occurred to a healthy man inhaling for an operation for fistula in ano.

IV. *Signs of simultaneous arrest of respiration and heart's action.*— In these cases it has seemed to me that, from the mode of administration, an inspiration of a highly-charged atmosphere has been taken, and hence the sudden arrest of pulse and breathing.

* Snow, case 42.

† See 'Lancet,' 1858, pp. 595-630. 'Med.-Chir. Rev.,' Oct., 1858.

‡ 'Lancet,' Sept., 1860.

CHAPTER XI.

NATURE AND MODE OF DEATH FROM CHLOROFORM.

The question as to the manner of death in fatal cases has been a "quæstio vexata." Does it occur by palsy of the heart, or by suffocation?

As far as we have gone, we have seen that the symptoms of the great majority have been those of the former of these causes; but there have been a few cases manifesting signs of the latter.

In the controversy which has existed, the mistake has been for each writer to adhere to his idea of death by the one method to the exclusion of the possibility of death by the other; and the teaching of experiments upon animals has been cited in too positive a manner.

According to the experiments of MM. Lallemand, Perrin, and Duroy, and of myself,* upon dogs, it is found that the movements of the heart in these animals persist after the movements of respiration have ceased.

Dr. Snow found, in the first experiments made to elucidate the manner of death from anæsthetics, that whilst in cases of inhalation of dilute atmospheres (3·6 per cent.) the movements of the heart of the dog persisted long after the cessation of respiration, in cases of concentrated atmospheres (8 per cent. and upwards), the arrest of the heart was either just before or immediately after the cessation of breathing. Dr. Anstie's experiments confirm this.

Mode of death in dogs from small doses.†—The first sign is enfeeblement of the costal respiration; the breathing by the diaphragm becomes more apparent. Soon diaphragmatic respiration greatly predominates, and coincidently the circulation becomes feeble and irregular. The walls of the chest now scarcely move at all in respiration; the last struggle for breathing is made by the muscles of the face; the lips tremble, the nostrils dilate, and there are a few contractions of the muscles

* See 'Lancet,' May 11th, 1861.

† 'Stimulants and Narcotics,' p. 372.

which go from the lower jaw to the ribs. All respiratory acts then cease, and yet the heart beats rhythmically for two or three minutes afterwards. After it has ceased to beat it is yet susceptible to stimulus for a considerable time. Pricking it or galvanising its fibre causes contraction.

Mode of death in dogs from large doses.—The sequence of symptoms is the same, but the rapidity is greatly augmented. The arrest of diaphragmatic respiration is directly accompanied by the last struggle of the respiratory muscles before mentioned, and the heart continues to beat for only a very short time. The stronger the dose, the more rapidly does the heart succumb, and it is found on the application of stimulus to be almost inirritable.

A lesson is hereby pointed. If free dilutions are administered the heart is susceptible of stimulus even after pulse and breathing have been brought to a standstill. Hence there is a good chance of resuscitation if only dilute atmospheres have been employed. If, on the other hand, the dose has been strong the irritability of the heart fibre is destroyed, and no amount of stimulus will make it contract again.

On comparing the phenomena in the case of these animals with those of fatal chloroform-narcosis in the human subject, it is at once seen that they are not identical: for while, in the latter case, both in instances of moderate and of concentrated doses, the heart is nearly always the first to succumb; in the former, the heart is, in almost every case, the last to die.

Furthermore, that it is impossible to establish the idea of one particular mode of death in case of animals and man is shown by the varieties in the behaviour of animals themselves. In guinea-pigs, I have found the heart to withstand the influence of chloroform more than in the case of dogs. Though temporarily paralysed, it will resume rhythmical contraction. Going lower in the scale the resistance increases. The heart of a snake will continue to contract after removal from the body, even if it be plunged into a bath of chloroform.

Reverting to our first considerations we may explain this apparent variation of plan. The whole system is traversed by an imperfectly vitalised blood; what link in the chain is first to be snapped asunder is determined by subtle, and, perhaps, inexplicable influences. Whether the impure blood in the

heart's substance abolish the excitor stimulus, whether defective nutrition of the nerve-centres abolish the motor stimulus or whether there be, in like manner, palsy of the excitor or motor influences on respiration, is determined by various causes.

The heart, in which first circulates the altered blood, appears to have the worst chance; and, in man, it is generally first to succumb. This tendency, however, is antagonized by its own inherent automatic powers, which are marked in the inferior warm-blooded animals, and still more so in those of cold blood. The power of the heart to resist the direct influence of chloroform is directly proportionate to the energy of its contraction when independent of the nervous system. In man the emotional and nervous influences upon the heart are, of course, at the highest degree; and these diminish in a direct ratio as we pass from the higher to the lower animals. This consideration, in my mind, explains with a great deal of probability the comparative immunity of children from the fatal effects of chloroform. The inherent irritability of the heart of infants is a resistance to the paralysing power of chloroform.

The next point to be noticed is the POST-MORTEM APPEARANCES in cases in which chloroform has proved fatal.

The most complete and trustworthy experiments upon animals are those which have been recorded by Messrs. Lallemand, Perrin, and Duroy. The following is an epitome of their conclusions.

The *lungs*, when the autopsy was made shortly after death, were found to be of a rose colour, presenting no sign of congestion, ecchymosis or emphysema. When the post-mortem was made, the day after death, there was hypostatic congestion of the depending portions.

The right cavities of the *heart* and the large veins were filled with dark fluid blood. The left cavities were generally empty, but occasionally contained a small clot.

The *brain and nervous tissue* appeared to be normal, not congested.

Chloroform has been detected by these experimenters, after death from its inhalation, in the following proportions in the different tissues:—Blood, 1·00; brain, 3·92; liver, 2·08; flesh, 0·16.*

* The "Report of the Committee on Chloroform" presents little to be added to these details. In the lungs of animals killed by chloroform it

The most noticeable post-mortem appearance is, therefore, distension of the right side of the heart with dark and fluid blood. This was supposed by Dr. Chapman to be the immediate cause of death; but Messrs. Lallemand, Perrin, and Duroy consider that it is effect and not cause; the blood being imperfectly arterialised by the arrest of respiration, and the heart continuing to contract after this arrest. Palsy of respiration by subdual of the motor influence from the brain is, therefore, according to them, the primary cause of death.

Turning from animals to the human subject, we will next consider a summary of the post-mortem appearances in fifty-one deaths from chloroform.

Fifty-one cases.

Blood dark and fluid	24
Lungs congested	18
„ in depending parts	4
loaded with blood	5
normal	10
Heart. Accumulation of blood in right side	17
In three cases distended; in all the cases there was little or no blood in the left cavities. The blood was fluid in all but two cases. In one case air was mingled with the blood.	
All cavities empty	9
In one case contracted as from spasm.	
All cavities containing blood	13
In one case a firm coagulum was found. Galvanism had been employed.	
Auricles empty, ventricles containing blood	2
Brain congested	9
normal	14
pale	7
Air in vessels of brain	1

seems that the Committee found more evidence of extravasation of blood than was noted by Messrs. Lallemand, Perrin, and Duroy. As to the brain, it is stated that, though the vessels on its surface were found full of blood, those in the interior of the cerebral substance contained no more blood than usual.

"From these facts it is clear that, although there may, in certain cases, be an impediment to the free circulation of the blood through the lungs, yet the appearances after death has been caused by chloroform are very different from those observed when life has been destroyed by asphyxia. In death from chloroform all the cavities are distended, and the cases are only exceptional in which the left side is empty. The rule, however, is alike in both—that the cavities of the right side contain more blood than those of the left."—'Med.-Chir. Trans.,' vol. xlvii, pp. 336, 339.

An almost constant sign was darkness and fluidity of the blood. In only three cases was there any coagulum. These coagula were in two cases soft, in the other very firm; in this instance its formation was attributed to the galvanism employed for resuscitation. The fluidity of the blood explains its tendency to hypostasis in so short a time. It explains, in a great measure, the variation from congestion to pallor in the lungs and brain. Neither of these organs afford positive data for the elucidation of the problem of death from chloroform; but analogy with animals shows that death is not due to any special congestion, the appearances of engorgement being entirely due to the gravitation of the very fluid blood.

As in animals, so in man, a frequent sign is accumulation of blood in the right chambers of the heart; but there is this difference, that whilst in the case of the former it is constant, in the latter it is not so. In thirty cases the right side contained blood in greater or less proportion, in nine cases it was empty.

From a review of the foregoing circumstances, it seems that —(1.) In animals, death occurs in a definite manner—by that form of asphyxia which is due to the suspension of the motor power supplied to the muscles of respiration. Death may be said to commence in the brain. (2.) In man, death occurs by a more complex mode, modified by general conditions of system; by emotional influences, by the methods by which chloroform is administered.

Death in the human subject may take place by three modes: I. By syncope. II. By asphyxia. III. By necræmia.

The death by Syncope may be in one of two forms—(*a*) in consequence of the loss of the irritability of muscle. These are cases in which, after death, the heart is found flabby: in which blood is distributed throughout its cavities. This is the common form of death, and is akin to death from shock. We may readily see how this form may be superinduced by violent emotion, by sudden fear; we have also seen that such may occur from the influence of sudden inspiration of large doses, the irritability of the muscular structure being all at once destroyed. And when, as in cases of fatty disease, this irritability is to a great extent destroyed, we may understand how that patients suffering therefrom are prone to this accident. There appears to be in these instances a sudden

influence on the sympathetic system, a sudden palsy. Such we have seen in frogs when large doses of chloroform have been suddenly administered. There has been dilatation of the capillaries and sudden arrest of the circulation. But Syncope may occur from the second form—(*b*) tonic spasm. This is not usual, but has occurred; the heart having been found firmly contracted and containing no blood. Here would seem to be a sudden influence on the sympathetic—an irritation, not a palsy.

The death by Asphyxia may be peripheral or central—(*a*) from disorder of the lungs themselves, as in cases of disease wherein a rapid congestion may be superinduced; or (*b*), from suspension of the motor power, such as occurs in animals, and such as is induced in the human subject when the last symptoms are those of a profound coma.

Death by Necræmia occupies a position between these more decided forms. Death is due to a faulty condition of the circulating blood, which at one and the same time enfeebles the heart, impairs the activity of the nervous system, and prevents the due performance of the vital changes in the systemic capillaries.*

CHAPTER XII.

RESUSCITATION IN APPARENT DEATH FROM CHLOROFORM.

In 1853-54 the Medical Society of Emulation in Paris appointed a Committee to inquire into this important point. The same has occupied the attention of the committee appointed by the Medical and Chirurgical Society of this country. This co-operation and correlation have produced results which are definite and satisfactory. I shall consider the results which have thus been arrived at, together with certain points of the evidence of individual experience.

All existing facts, and all the latest experiments, point to the conclusions that there is only one perfect stimulus to the failing heart, the stimulus of a sufficiently aërated blood,

* See Dr. C. J. Williams' 'Principles of Medicine,' p. 468.

and that the only mode of producing it is the excitation of respiration. Local stimuli to the heart are of no avail; the stimulus must originate in the lungs. Messrs. Lallemand, Perrin, and Duroy observe, in their work on the 'Rôle of Anæsthetics in the Organism,' "Animals, etherized so far that the movements of respiration cease, all die if left to themselves. If, on the other hand, even when the heart no longer beats, artificial respiration be made to take the place of the suspended natural respiration, the animals in a state of apparent death return to life and recover the exercise of all their functions."

The mode of inducing artificial respiration in animals has usually been the introduction of a sound into the trachea, the inflation of the lung by means of an ordinary pair of bellows, and the compression of the walls of the chest, the movements of natural breathing being thus imitated. Life has usually returned in between three and four minutes.

Another mode analogous to this has been Faradization of the phrenic nerves, whereby artificial respiration is produced by the alternate contraction and relaxation of the diaphragm. This proceeding, assimilating the most closely to the respiratory action during life, is, of course, a most valuable one; and it has this advantage, that it can be kept up for a prolonged period with perfect regularity. If the conductors of a sufficiently powerful interrupted galvanic current be placed, the one on the neck near the origin of the phrenic nerve, and the other over a part of its course, the diaphragm contracts, and an inspiration is produced. If one conductor be then removed the diaphragm is again relaxed, and an expiration is the consequence. The French Committee has recorded several experiments.

To quote two of these:

A dog is put under the influence of dilute atmospheres of chloroform. At the end of eleven minutes respiration ceases; in a few minutes the heart flutters, and then stops. The conductors of a galvano-faradic machine are applied, with the intervention of wet sponges, on the neck over the course of the phrenic nerves. The current is interrupted every two seconds. As it passes, the hind limbs are stretched out, the abdominal walls expand, and air enters the lungs with a sobbing sound—the thoracic cavity, in fact, is enlarged, both vertically and (as to its base) transversely. When the current is broken the

abdomen and chest fall as in expiration. The expiratory movements are aided by manual compression of the thorax. At the end of three minutes contractions of the nostrils, eyelids, and tongue occur, and a minute afterwards there is a natural inspiration, soon followed by others. Then the normal respiratory movements are restored. Faradization is discontinued, having lasted four minutes; twenty-five minutes afterwards the animal is completely restored.

In another experiment a dog is exposed to a strong atmosphere of chloroform. The movements of respiration are arrested in two minutes, and a few seconds afterwards the heart ceases to beat. Immediately the phrenic nerves are Faradized, as in the other experiment. For two minutes no spontaneous respiratory movement occurs. Then the nostrils move, the animal winks, and in two seconds afterwards begins to breathe. The Faradization being continued, the animal makes two or three deep inspirations. Complete restoration takes place in a quarter of an hour.

Inflation of the lungs with gases instead of with atmospheric air has been tried. Oxygen, hydrogen, and nitrogen, have been employed.* But in the first place, it has been found that oxygen has no greater power to remedy the mortal effects of chloroform-narcotism than atmospheric air; and, in the second, that even the irrespirable gases hydrogen and nitrogen are capable, if the lungs be alternately distended with them and emptied, of causing reanimation. In the latter case, of course, directly the mechanical movements are restored it is necessary that the respiration of these gases, which are in themselves poisons, should be discontinued.

Simple stimuli valueless.—A momentary survey of the conditions will convince us why our only hope is in re-establishing respiration. The system has imbibed a volatile body capable of suppressing the functions of the blood. It does not produce any mortal influence over the functions of respiration or circulation so long as there is a sufficient compensatory oxygenation supplied by a sufficiency of pure air. But it may accumulate; imbibition may not proceed *pari passu* with elimination, but may be in excess. Symptoms of danger occur. Simple stimuli are of no avail, for of what use is stimulus to the heart, which may excite it to action for a few minutes, when the con-

* Report, 'Union Médicale,' 1855, vol. ix; Cl. Bernard, 'Leçons sur les effets, &c.," p. 232.

ditions remain unchanged, the noxious element uneliminated? Dr. Snow says, "Such measures as dashing cold water on the patient and applying ammonia to the nostrils can hardly be expected to have any effect on a patient who is suffering from an over-dose of chloroform, *for they would have no effect whatever on one who has inhaled it in the usual manner, and is merely ready for a surgical operation, but in no danger.* I have applied the strongest ammonia to the nostrils of animals that were narcotized by chloroform to the third or fourth degree, and it did not effect the breathing in the least. They recovered just as if nothing had been done." Furthermore, direct pricking of the heart and galvanism have been tried, but though they provoke a few contractions they have never restored continuous heart's action.

Rationale of the action of Artificial Respiration in resuscitation.—Artificial respiration acts, first, by ELIMINATION; secondly, by STIMULUS. The first efforts expel the vapour already (left behind) in the lungs; then the inspired air becomes a stimulus upon the mucous surface; the result is a reflex action, the production of movements of the heart and movements of respiration. Each time more and more of the chloroform-vapour escapes from the lungs, and is taken away in the expired air. So the system becomes unloaded, as it were, and the entering air becomes a more and more perfect stimulus. It is the mechanical disembarrassment which is of the first importance.

"Artificial respiration," say MM. Lallemand, Perrin, and Duroy, "awakens circulation, respiration, and life by introducing into the chest, by a to-and-fro movement, a gaseous current, which acts in virtue of its physical, and not of its chemical properties." They go on to say that the artificially produced respirations restore the breathing functions only by re-establishing the necessary mechanical movements; because the insufflation of irrespirable gases has succeeded in recalling the action.

I consider that MM. Lallemand, Perrin, and Duroy have lost sight of the first cause of this reanimation. They speak of the inspired gas, or the mechanical distension of the chest, as producing a stimulation of the mucous surface of the lung, and thus primarily invoking reflex action. But the system is insusceptible of this invocation; the heart and lungs do not respond primarily; reflex action is

abolished. The explanation I consider to be this—the gaseous current entering in and passing out carries away with it the chloroform-vapour which is in the air-cells of the lung, just as the strokes of a pair of bellows would dissipate a drop of chloroform which might be in the interior. By the continued action still more chloroform-vapour is blown out, as it were, from the very lungs themselves. They become gradually disembarrassed from the vapour which was abrogating the vitality of the blood; the blood itself is set in motion by the mechanical acts of inspiration and expiration, and circulation returns.

Value of Warmth as an adjunct.—The usual practice is, whenever a patient is in a state of danger from chloroform, to open the windows and let in a current of cold fresh air upon him. Cold water is dashed upon the face and chest to excite spasmodic inspirations. As to the efficacy of the latter, Dr. Snow has well observed that it would be "nil," even in the case of the ordinary symptoms produced by chloroform. It is quite certain that if this proceeding has been successful it has only been in those cases in which a few pressures upon the chest would have reinstated breathing.

I believe both these measures to be pernicious. It has been shown that the first desideratum is respiratory action, irrespective of the quality of the air breathed. The windows should not be opened until respiratory acts have commenced.

The next desideratum is warmth. In the case of persons apparently dead from drowning (cases which have much in common with those of threatened death from chloroform), Dr. Christian has stated that warmth is an immediate and powerful excitant, and that frequently those in whom respiration had ceased, on being put into a warm bath, gave signs of return of breathing.* In one most remarkable case warmth and friction, persevered in for eight and a half hours, restored life.† "It ought certainly to be borne in mind that the practice of the Royal Humane Society, whose rules may be summed up in one word —warmth!—has been eminently successful."‡

In the published rules warmth has not been insisted on strongly enough *during* the inspiratory efforts. It has rather

* Paper "On the Restoration of Suspended Animation in Persons Apparently Drowned."

† Taylor, 'Medical Jurisprudence.'

‡ Silvester, see 'Brit. and For. Med.-Chir. Rev.,' April, 1858.

been deferred till after the restoration of breathing. I believe it to be most important during the attempt at resuscitation, and any current of cold air or any application of cold water is a positive mischief. By warmth is not necessarily implied the warm bath, because this may, to some extent, interfere with the breathing efforts. Nothing should interfere with them, but warmth by hot flannels or by a supply of hot air can be applied without a moment's interruption.

Dr. Richardson adduced several considerations tending to establish the value of warmth, and I, at the same time, urged its importance in a paper read before the Western Medical and Surgical Society of London. I performed the following experiments:

(1) The movements of the exposed heart of a kitten were arrested by chloroform-vapour, then a jet of steam was directed upon the organ; the effect was instantly to restore rhythmical contraction.

(2) A rabbit was chloroformed till apparent death took place. After a few inflations of the lungs the chest was opened and the heart found beating rhythmically. Warm air of a temperature of 98° Fahr. was blown into the lungs by means of a pair of bellows, an elastic catheter being introduced into the mouth. The heart's pulsations were certainly increased in force and rhythm, a contraction of the ventricles taking place just after each inflation.

Cold air of a temperature of 40° Fahr. was then injected instead of the warm air. There was first a spasmodic pulsation, and then the pulsations became decidedly more feeble. At every insufflation they became feebler still.

Warm air again increased the rhythm and force of the heart. Cold air again enfeebled it. Its irritability was now gone (except in the left auricle), and pricking it with a needle failed to cause any decided contraction.*

Friction is also an important auxiliary. It should be so applied as to force the blood from the extremities towards the heart. The very motion of the blood becomes a stimulus to the heart's contraction.

We have said that the usual sign of danger in chloroform-

* It is interesting to note how thoroughly Hunter was impressed with the value of warmth as an adjunct to artificial respiration. See Hunter's collected works, edited by Palmer. Chapter entitled "Proposals for the Recovery of Persons apparently Drowned," vol. iv, p. 171 *et seq.*

administration has been failing of the pulse; embarrassment of the respiration has been a marked sign in only a minority of cases. If, therefore, artificial respiration were efficacious only in those cases in which the heart's action still continued, its value would be limited—in the multitude of cases it would be hopeless.

The Medical and Chirurgical Committee has stated that, though resuscitation may *sometimes* be effected even after the cessation of the heart's action, this result is exceptional.

On the other hand, a number of cases is recorded in which the means employed were successful even though the heart had probably ceased to beat.

Restoration after the cessation of the pulse.—In the first case of resuscitation recorded the pulse had ceased, but artificial respiration restored the patient (Ricord). In a case recorded by Mr. Broadbent the heart had ceased to beat,* the pulse had quite stopped. Artificial respiration and tracheotomy restored the patient. In another case the alarming sign was that the blood issuing from the wound made for the removal of an adenoid tumour of the breast ceased. The heart had, of course, failed. Artificial respiration was commenced, and at the end of three minutes the pulse began to return; in six or seven minutes there was recovery.† A third instance is recorded by Dr. Burge, of New York. Chloroform was given to a young lady for the performance of amputation of the thigh. The respiration ceased, the pulse could not be felt, and the jaw dropped, but artificial respiration restored life.‡ A fourth is recorded by George Wigan, Esq.§ In a fifth, after respiration had ceased, the pulse ceased, and all around thought that death had taken place. Tracheotomy performed immediately, and artificial respiration kept up for an hour and a half, restored life.‖ In a sixth case, a girl of six, the pulse ceased—"there was no pulse for a quarter of an hour." Artificial respiration kept up for half an hour restored life.** In a seventh, a boy of four, the pulse *had quite ceased*, the jaw had dropped, and the body had become corpse-like. Artificial respiration, continued by means of Faradization of

* 'Lancet,' Nov. 30th, 1860.
† 'Gaz. des Hôpitaux,' No. 76, 1858.
‡ 'Med. Times,' 1858, vol. i, p. 416.
§ 'Med. Times,' June 26th, 1858. ‖ 'Deutsche Klinik,' 1859, No. 4.
** 'Med. Times,' 1859, vol. i, p. 9.

the diaphragm, restored life. The teaching of this array of cases is surely that it is folly to desist from efforts of reanimation because the pulse has ceased. Far from resuscitation being rare in these instances, I have found that the restored cases have generally presented a history of the pulse having ceased first.

CHAPTER XIII.

RESUSCITATION—PRACTICAL DETAILS—SUMMARY.

It has been said that stimuli merely directed to the heart are useless to counteract the ill effects of chloroform. The only efficient stimulus is respiration.

The heart has been punctured with needles, galvanized, and otherwise irritated, the pneumogastrics have been stimulated but to no purpose further than causing a temporary pulsation. Restoration has not been accomplished by these means.

Importance of pulling the tongue forwards.—When danger from any cause occurs in the course of chloroform-administration the tongue is apt to fall back over the aperture of the glottis.

If the symptoms of danger are sudden and early, the tongue, instantaneously paralysed, falling by its own weight, blocks the entrance. At the first onset of anæsthesia the tongue, locally affected by the vapour, becomes partially insensible, and its movements are partially out of control. In the advanced stages it partakes a greater amount of the general paralysis, and by its weight impedes the respiration and deepens the stertor.

At every adverse sign, therefore, the tongue should be well drawn forwards. Thus favoured, the entrance of air may be induced by spontaneous inspiration ; if not, it is still as important during the artificial respiration. The value of the expedient was recognised by Mr. Bickersteth* at an early period of the history of chloroform. He quotes a case in which death seemed

* 'Edin. Monthly Journal,' 1853.

to have taken place. "I felt certain that the man was dead, and that no human aid could restore him; and if it had not been that those standing near me urged me to persevere, I believe I should have deserted the case as hopeless. Just at this time it occurred to me to put my finger in the mouth and draw forward the tongue, in order to ensure there being no impediment to the air entering the lungs. Retaining it in this position we again began the artificial respiration, and found that the chest was fully expanded by each inflation." This case ended in recovery, and the importance of the means suggested has been fully recognised subsequently.

The finger may be used to hook the tongue forwards, or its tip may be seized with a pair of forceps, vulsellum or artery forceps being the best for the purpose. The finger and thumb covered with a handkerchief constitute probably the best means.

METHODS OF ARTIFICIAL RESPIRATION.—(1) *Mouth-to-mouth insufflation.*—M. Ricord first succeeded in restoring two patients to animation by mouth-to-mouth inflation of the lungs. So, at the early period of the use of chloroform, it was hoped that the universal remedy for chloroform over-action had been discovered. The history of the cases shows that recovery is more probable in those cases in which the respiration ceases, the pulse continuing.*

Dr. Snow relates the following successful case:—A patient, a lady over sixty years of age, required to have a polypus removed from the nose. She seemed to be in a state of great alarm: just at the time when insensibility occurred the breathing ceased and the pulse could not be felt. (Sympathetic paralysis—Syncope.) No heart-sound could be heard. Mr. Fergusson, who was about to perform the operation, applied his mouth to that of the patient, and by a powerful expiration inflated her lungs. A few more inflations were made at intervals. At first the heart assumed a very rapid and feeble action, then the patient made several gasping inspirations, and soon natural breathing and pulse were re-established.† A narrow escape from a fatal result is recorded.‡ The sign of danger was the fact that, in the course of an operation for the removal of a tumour of the breast, the escape of blood suddenly

* See Bickersteth, 'Edin. Monthly Journal,' 1853.

† Snow, p. 260.

‡ 'Gaz. des Hôpitaux,' No. 76, 1858.

ceased; the action of the heart had stopped. M. Démarquay immediately practised mouth-to-mouth inflation of the lungs. After the lapse of three minutes a feeble pulse returned; in six or seven minutes danger was over.

These cases are enough to show that this ready means is most important for overcoming the signs of danger in chloroform-narcotism. Mouth-to-mouth insufflation is of especial importance when the adverse signs are sudden and early, whenever, as I have before said, there is sudden sympathetic paralysis. In cases in which elimination has to be carried further, where there is a profounder influence of the chloroform upon the system, a method which is capable of greater protraction is indicated.

(2.) *Compression of the Thorax. Postural Methods.*—When adverse symptoms occur in children of tender age—the mere compression of the chest with the hands with alternate relaxation will generally induce a gasp, and reanimation will be accomplished. I have often thus, with infants, not only recovered them from any dangerous symptoms, but have hastened the respiration in ordinary cases, and so expedited the recovery.

Chloroform was given to a young girl for the performance of amputation in the thigh. The chloroform was impure. After a while the pulse became imperceptible, the breathing ceased, and the jaw dropped. Artificial respiration was commenced and sustained by the Marshall Hall method, together with manual compression of the chest. The means were ultimately successful.*

An instance of a like success is also recorded by G. Wigan, Esq. Cases are related in which artificial respiration has been kept up for half an hour or more with ultimate success; and it is important to note that in one case a *quarter of an hour* elapsed before there was any sign of return of heart's action. A moral this against any lukewarmness of proceeding, and an incentive to persevere long against adverse signs.

Dr. Marshall Hall's method.—The essential proceedings are to place the patient on the floor or table, face downwards. To turn him well and instantly on the side: To replace him on the face, raising and supporting the chest on a folded coat or any convenient pad: To

* Dr. Burge, of New York, 'Med. Times,' 1858, vol. i, p. 416.

turn the body very gently on the side and a little beyond, and then briskly on the face again, repeating these measures deliberately, efficiently, and perseveringly, about fifteen times in the minute, varying the side; every time that the body is replaced on the face making firm pressure on the back between the lower angles of the shoulder-blades.

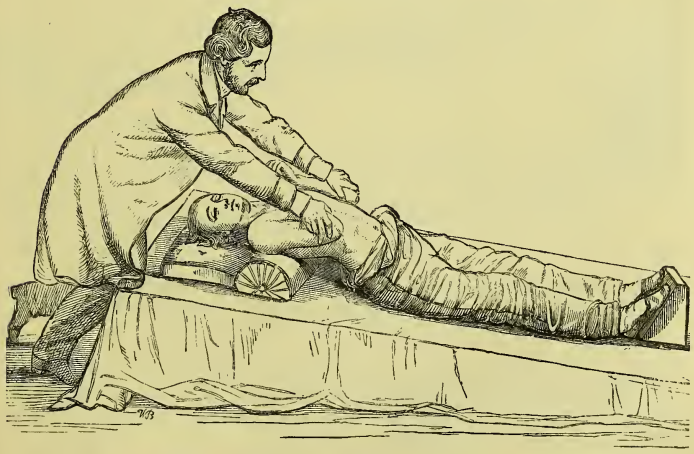
In Dr. Marshall Hall's plan it is not recommended to apply any warmth to the body or to promote the circulation by friction until natural respiration is restored.

This method commences, as is right in these cases, with Expiration.

Dr. Silvester's method.—The essentials of this method, in case of danger from chloroform, are:—

Fig. 7.

I. Expiration.



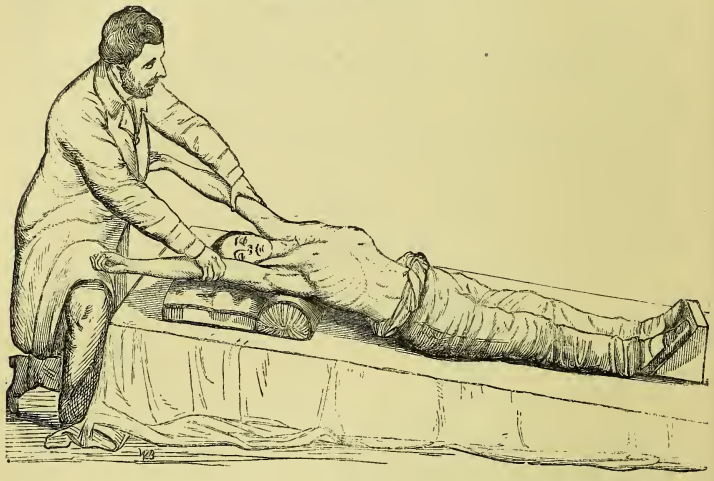
Dr. Silvester's method of resuscitation. First effort, to expel air from the chest.

To draw forwards the tongue and keep it by an elastic band or otherwise. To replace the patient on a flat surface, slightly inclined from the feet upwards, the chest being elevated on an impromptu cushion: Then, grasping

the arms, to press them firmly against the sides of the chest (fig. 7):* Next, immediately to raise the arms by the sides of the head and keep them stretched steadily upwards and forwards for two seconds (fig. 8).

FIG. 8.

II. INSPIRATION.



Dr. Silvester's method. Producing expansion of the chest.

Repeat these measures alternately, with long perseverance and unfailing regularity, fifteen times in a minute.†

* This is reversing the order of proceedings which obtains in the case of drowned persons, but it enables the process to begin, as it should, in cases of danger from chloroform, with *expiration*. This should be followed *immediately* by an inspiratory effort.

On all points connected with this proceeding, see 'The Discovery of the Physiological Method of inducing Respiration in cases of Apparent Death from Drowning, Chloroform, Still-birth, Noxious Gases, &c., by Henry Silvester, B.A., M.D., Lond.'

The author desires to express his acknowledgments to Dr. Silvester, as well as to Mr. Young and the Royal Humane Society, for their courtesy. The Stereotypes were kindly lent by the Society.

† In case of either of these postural methods being adopted in chloroform accidents, I consider, with my friend Mr. Watson, that the rapidity

In this proceeding the application of warmth to the surface is more feasible; even the warm bath may be employed without the necessity of suspending the manual process.

EXPIRATION, *i. e.*, EXPULSION OF THE AIR ALREADY IN THE CHEST, OF THE FIRST IMPORTANCE.—When the natural movements of respiration have ceased, there is yet a quantity of air left in the lungs. In the case of chloroform-administration this air is, of course, impregnated with chloroform. After expiration the lungs will retain about 170 cubic inches (Herbst). This residual atmosphere of chloroform is absorbed after the continuous inhalation is discontinued; hence the deepening of the symptoms of narcotism in ordinary cases when the administration is suspended.*

In cases wherein apparent death has occurred, therefore, there is yet a residual quantity of chloroformed air in the lungs. It is obvious that the first efforts should be directed to the getting rid of this.

Dr. Marshall Hall's method expels it in a slight degree. The method commences with expiration, but the bulk of air expired is but slight.†

Dr. Silvester's plan effects it in a much more satisfactory manner.

Pressure by both hands on the lower third of the sternum displaces from eight to ten cubic inches of air. Pressure on each side of the thorax displaces about the same amount.

These efforts to expel the air should be first made, and then the ordinary process persevered in.

The following are the conclusions of the Medical and Chirurgical Committee:

"From experiments on animals, and also from a consideration of cases of accidents with chloroform in the human subject, the committee is strongly of opinion that the first and most important means of resuscitation is artificial respiration. Certain other methods may prove of service in aid of that, as

of the necessary movements might be very much increased. Because a man breathes fifteen times a minute in a state of health, it by no means necessarily follows that efforts to expel air charged with chloroform from his lungs should be in the same ratio. On the contrary, it seems more rational to promote the quick expulsion of the vitiated air and the speedy introduction of a current from the atmosphere.

* Snow, p. 91. Sedillot, 'Gaz. Médicale,' Jan. 15th, 1848.

† Trans. Royal Med. and Chir. Society, 1862.

the principal one; but they are all objectionable, in so much as they delay the commencement of the artificial respiration.

"It is of the most pressing importance that artificial respiration should be commenced the moment that alarming symptoms exhibit themselves. The delay, even of a few seconds, will doubtless, in some cases, destroy the only chance of life.

"Artificial respiration should be practised in the manner known as Dr. Silvester's method, and as recommended by the Committee on Suspended Animation. . . .

"Mouth-to-mouth insufflation is a most valuable method of resuscitation. By it several good recoveries have been effected, a large quantity of nearly pure air being blown into the chest at each insufflation. In all cases in which it is employed the nostrils should be closed and the larynx should be pressed against the spine, to prevent the escape of air down the œsophagus."*

3. *Galvanism of the Phrenic Nerve.*—It has before been stated how complete is this method in supplying the want of the natural efforts of respiration.

A boy, æt. 4, in the course of chloroform-administration assumed all the appearances of threatened death. The face became livid, the pulse ceased, the jaw dropped, the appearance was exactly that of a corpse, and all the bystanders thought that life was extinct. Artificial respiration was immediately commenced, with methodical compression of the chest. Then Dubois-Reymond's galvanic apparatus was sent for. One pole was placed over the situation of the origin of the phrenic nerve (where the omo-hyoid muscle crosses the sterno-mastoid), the other was applied to the seventh intercostal space. Contraction of the diaphragm followed. The proceeding was intermitted and repeated, to imitate natural respiration, and after a time a slight spontaneous pulse became perceptible. Methodical compression of the chest-walls was again concurrently resorted to, and in time recovery became complete.†

Dr. Kidd adduces a case in which this method was again successful.‡ In this instance the skin was punctured, and the current passed after the insertion of the pointed conductors.

* "Report of Committee," 'Med.-Chir. Trans.,' vol. xlvii, p. 349.

† 'Archiv,' B. xvi, p. 527.

‡ 'Med. Times,' March 28th, 1863.

Mr. Harry Lobb* has observed that the actual insertion of pins is wholly unnecessary; it is only required that the conductors, covered with wet cloth, should be applied to the surface of the skin. He says that it is better for conductors to be on either side of the neck, *i. e.* over both the phrenics.

The current should be sufficiently strong to cause the proper muscular contraction, but should not be too powerful. One reophore should be placed over the point of crossing of the omo-hyoid and the sterno-mastoid; the other may be near the first, along the course of the phrenic or at its periphery, over the diaphragm. The current should be interrupted at regular intervals, to imitate natural respiration.†

Description of apparatus.—It had better here be observed that the efforts at the promotion of breathing must not be intermitted a single moment for any search for apparatus. A messenger may be despatched for the most available instrument.

An ordinary magneto-electric arrangement for medical use will answer the purpose, or any of the usually employed cells in connection with an induction coil.

The best and most compact instrument that I am acquainted with is the Marié-Davy arrangement, made by Mr. Ladd, of Beak Street. It is highly recommended by Mr. Harry Lobb, and certainly has the merits of great portability, cleanliness, and high electro-motive force. It has the form of a book, the cover of which being opened, discloses only the wires and attachments of the induction coil, which is contained in a compartment to the right. The generator is in a small drawer to the left; it consists of a cell of carbon lined with a piece of lint, superimposed on which is a slab of zinc. This little battery is excited by a few grains of sulphate of mercury

* 'Med. Times,' April 4th, 1863.

† "With reference to the employment of galvanism, it may be noticed that the most powerful effects were those produced when galvanism was applied to the neck; and little difference was observed whether the poles were laid on opposite sides of it, or when one being placed on the front of the neck, the other touched the lower part of the chest."

"Galvanism requires to be used only in a very moderate intensity, and it is necessary to employ it in an interrupted current, and to leave frequent intervals of repose. Strong and continuous currents appear rather to exhaust than to restore muscular activity."—'Report of Chloroform Committee.'

which are placed upon the lint and *just moistened* with a little water; thus all slop and mess are avoided.

Fig. 9.



Electro-Magnetic Apparatus complete.

By drawing out or pushing in the soft wire in the centre of the coils, the force of the current is increased or diminished, and it is still further increased, if need be, by connecting the transmitting wires with the secondary instead of the primary wire of the coil.* The conductors recommended by Mr. Lobb are flat metal discs, which, for the purpose we are considering, should be covered with moistened cloth, and should be provided with india-rubber (non-conducting) handles.

Apparatus for inflating the lungs.—After advising the performance of artificial respiration in the admirable manner originated by Dr. Silvester, the Chloroform Committee goes on

* Details as to this apparatus are contained in the 'Electrician' for March 18th, 1864.

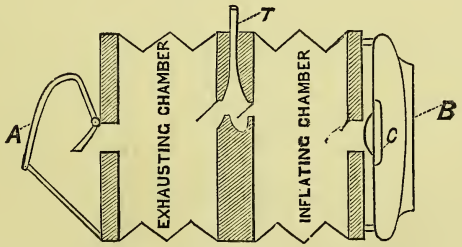
to state—"Those who are conversant with the use of the bellows, adapted to artificial respiration by Dr. Marcet, may effect a yet more perfect and deep artificial breathing, since by means of it a much larger quantity of air may be made to enter and to leave the lungs, and one chief object, that of eliminating the chloroform, may be speedily accomplished."*

The advantages of the use of bellows, if these are at hand, are—

1. The speedy emptying and filling of the lungs.
2. The possibility of applying warm air to the pulmonary surface, and so more quickly stimulating the capillaries, and favouring the elimination of the chloroform-vapour.
3. The greater ease with which warmth can be applied to the surface of the body during the process of artificial respiration and the better opportunity of applying other remedial measures.

A very efficient form of bellows has been invented by my friend Mr. W. Spencer Watson. The following is a description of it:—The instrument is essentially composed of two chambers,

Fig. 10.



Mr. Watson's bellows for artificial inflation of the lungs. *A*. Handle of instrument. The valve opening outwards is attached to this handle. On pressing it the valve closes; on relaxing pressure it opens. *B*. Other handle attached by straps which pass through rings at upper and lower borders of inflating chamber. When this handle is drawn outwards the valve *C* is closed, but this valve can be opened at pleasure. *T*. Tube communicating with both chambers, to which is fitted an india-rubber pipe with nozzle.

* "Report," 'Med.-Chir. Trans.,' p. 349.

an exhausting chamber and an inflating chamber, both communicating with a tube for the entrance and exit of the air to and from the lungs. The valves of these two chambers are so arranged that the current can only pass in the direction required; but the valves in each side can be closed or opened at pleasure. An india-rubber tube is attached, and a double nozzle to fit the nostrils. A second tube, bent at right angles, for the trachea, can be adapted to the same for inflation after tracheotomy has been performed.

It is proposed that in adapting the nozzle to the nostrils pressure on the front of the larynx should be made, in order to prevent the air from getting into the œsophagus. With ordinary care there is no danger of rupturing the air-cells, though this has frequently been brought forward as an objection to the use of bellows.

Tracheotomy.—There are several reasons which concur to favour the *à priori* consideration that tracheotomy might be of service in threatened death from chloroform. If there has been sudden spasm of the glottis (as occasionally occurs concurrently with other adverse symptoms at the time of danger), or if the snoring noise of difficult inspiration has been continued during the period of peril, we may imagine that tracheotomy may be of service. When one considers that the mucous membrane, relaxed by palsy of all the subjacent muscular structure, may hang about the air-passage in loose obstructing folds, we can realise the desirability of introducing a current of air by a direct channel. In a case of alcoholic poison (wherein similar symptoms exist), tracheotomy has been successful.* Tracheotomy has been performed in several instances of threatened death from chloroform. One is recorded by Mr. Broadbent.† The pulse had stopped, and signs of death existed; tracheotomy was performed, a female catheter was introduced into the wound, and the lungs inflated. The patient completely recovered. A long time afterwards the patient came into the hospital for another disease and died there. A post-mortem was performed, and the heart was found to have undergone fatty degeneration. This explained the syncope at the time of the chloroform-administration.

An interesting case has been recorded by Prof. Langen-

* Dr. Marcet.

† 'Lancet,' November 3rd, 1860.

beck.* The bad symptoms commenced with suspension of respiration. At this time a silver catheter was passed down the throat, and the lungs were inflated; but, nevertheless, the pulse ceased, and all the bystanders thought the case hopeless. Tracheotomy was performed; no blood issued whilst the necessary incisions were being made, circulation was at a standstill. An elastic catheter was introduced through the wound into the trachea, and air was blown into the lungs. Artificial insufflation was kept up for an hour and a half. Muscular convulsions occurred, and for a long time there was complete absence of consciousness. Circulation and respiration were restored, the patient sank into a sleep which lasted through the night, and woke up well.

These two cases illustrate the extremes in the varieties of danger. The first case was one of sudden syncope, the second was an example of coma. In the first, the heart once set in motion, recovery was rapid; in the second there was a long period whilst the chloroform was being eliminated from the system, and recovery was tardy.

In any case tracheotomy *per se* is of no avail; there must be artificial respiration as well. This may be accomplished by a tube (such as a catheter) inserted into the trachea, and the lungs through it inflated by the operator; or the ordinary tracheotomy tube may be inserted, and the respiration be continued by the postural methods.

Concurrent stimuli.—Mention has been made of the value of warmth and of friction, the latter aiding the circulation of the blood.

Stimulants may be administered by the rectum. Brandy may be given in the form of enemata. A case is recorded of a little girl aged fourteen—a weak and emaciated child—who during the performance of an operation under chloroform became suddenly pale and pulseless. Artificial respiration was at once adopted, but no pulse returned for a quarter of an hour. A brandy enema was administered, and efforts at resuscitation were continued for half an hour. They were then successful.†

* 'Deutsche Klinik,' 1859, No. 4.

† Hunter recommended in cases of suspended animation stimulant injections both for stomach and rectum, and also the application of the "steam of volatile alkali" to the whole surface of the body.—Hunter's Works, vol. iv, pp. 172, 173.

Practical remarks.—If in the course of the inhalation you notice a sign of danger, if sudden pallor occurs, if the pulse fails, if after severe muscular excitement there is sudden collapse, or if there is an evident embarrassment of respiration, at once remove the chloroform, and—

I. Bring the patient to the recumbent position. The blood regurgitating from the system to the heart may induce in the latter renewed contractions.

II. With the finger, or with a pair of forceps, draw forwards the tongue.

III. Make a few alternate pressures by both hands upon the lower part of the sternum.

IV. *Commence Artificial Respiration.*—Having first brought the patient's arms to the sides, and exerted pressure against the walls of the chest to expel some of the air, lift the arms straight above the head, then bring them again to the sides and compress. Repeat this frequently, but be sure that it is done thoroughly, the arms well extended, and the chest firmly pressed. It may be well to let another press the lower part of the sternum so as to favour expiration.

Or, if Dr. Marshall Hall's plan of treatment be preferred—

Turn the body, from the position in which it lies, upon the side, or rather upon the sternum. This compression of the thorax first causes an expiration which forces the residual (chloroformed) air from the lungs.

[The efforts at resuscitation may be continued by mouth-to-mouth inflation of the lungs; but this, to a certain extent, is subservient to the muscular power of the chest of the inflator. Postural methods can succeed as well.]

Continue the alternate movement of the body from the posture on the back to that on the sternum twenty times in the minute.

V. At the same time let *warmth* be applied to the body. Let no cold air circulate near; do not dash cold water upon the chest.

Let friction be employed, the direction being from the toes upwards.

If there be a possibility, let a galvanic apparatus be sent for.

VI. If the apparatus is at hand, place the conductor (covered with wet cloth), which is in contact with the negative pole of the primary wire of the battery, over the phrenic nerve on the right side of the neck, pressing it well in;

the other conductor, also wetted, should be pressed into the epigastrium; now set the battery in action for one or two seconds—this will cause instantaneous contraction of the diaphragm—remove either of the conductors for ten or fifteen seconds, and repeat.

VII. If after five to ten minutes there is no recovery, or if the symptoms indicating danger have been characterised by difficult respiration or coma, perform tracheotomy, but continue your efforts at mechanical resuscitation. Do not relax the efforts, even if no sign of life return, for at the least half an hour.

VIII. Enemata of brandy and water may be administered during the process; and if the patient recover sufficiently to swallow, a little stimulant may be at once given.

CHAPTER XIV.

METHODS OF ADMINISTERING CHLOROFORM.

I HAVE said before (in Chapter IX), that I consider the administration of chloroform without stringent precautions to ensure dilution unsafe. The objections of what I cannot help calling the haphazard method of giving chloroform it is impossible to state better than in these words of Dr. Richardson* :—"To give chloroform on a linen rag, a piece of lint, or a sponge, is at once as unscientific as it is wasteful, and as wasteful as it is unsafe. Given in this way, no check whatever is put upon the quantity absorbed by the patient, while the surrounding air, charged also with the vapour, is annoying to the operator and to all around. I have seen a bystander obliged to leave the operating-table owing to the influence of chloroform-vapour, all of which was being wasted." I can add only one observation to this, which is that we should be as careful to dilute our chloroform with atmospheric air as we are to dilute the hydrocyanic acid which we administer to the stomach with a sufficiency of water, and that we should no

* 'Lectures on the Teeth.'

more excuse the administration of an indefinite proportion of chloroform than we should excuse the dispensing of a potent medicine without weighing it in a balance or measuring it in a graduated vessel.

I. *The Administration of a Definite Dilution of Chloroform.*—The Chloroform Committee of the Royal Medical and Chirurgical Society recommends that, "in order that it may be administered with comparative safety, it is necessary that the proportion of vapour should not exceed $3\frac{1}{2}$ per cent."

The most exact way of ensuring an exact proportion of chloroform-vapour is to prepare beforehand an artificial mixture with atmospheric air, preserving it in a receptacle from which it may be breathed by the patient. Dr. Snow tried this plan in 1849,* and found that the effects were produced most efficiently and regularly; the vapour was readily breathed and narcosis was produced in three or four minutes. The method adopted was to introduce into a balloon or bag of known size a measured quantity of chloroform, and then to force air in with a pair of bellows until the balloon was full. Dr. Snow adds, "I did not try, however, to introduce this plan into general use, as the balloon would sometimes have been in the way of the surgeon, and filling it with the bellows would have occasioned a little trouble. It seemed necessary to sacrifice a little of absolute perfection to convenience."

Mr. Clover's apparatus ('Med. Times and Gaz.,' August 9th, 1862).—The above method has been put into practice with much success by Mr. Clover. The apparatus he employs is, first, a bag for containing the anæsthetic mixture; secondly, an arrangement for filling the bag with a certain proportion of chloroform and air. The bag is of large size, capable of containing sufficient of the chloroform-atmosphere to serve for several cases of inhalation. It is lined with a film, of a material (such as gold-beater's skin) which is capable of resisting the solvent action of chloroform. A flexible tube leads from the bag to the mouth-piece, which is of the same conformation as that hereafter to be described as Dr. Sibson's; but Mr. Clover has introduced an improvement, by using for the valves thin plates of ivory, supported by spiral springs. The india-rubber which is usually employed for the valves is apt to curl up.

The apparatus for filling the bag with the atmosphere for

* 'On Anæsthetics,' p. 80.

inhalation consists of a bellows shaped like a concertina, with a receptacle for a definite amount of chloroform attached to its nozzle. This receptacle is a metallic box, which is kept warm by an interstratum of hot water, so as to facilitate the evaporation of the chloroform, which is received on blotting-paper in its interior. The lid of the box contains an aperture for the reception of a graduated syringe, by which the chloroform is supplied. Opposite that part of the box to which the nozzle of the bellows is attached is an open tube, to which the bag can be adapted. The apparatus being thus connected, air is blown over the chloroform into the bag by means of the bellows. For each thousand cubic inches of air which the bellows throws in forty minims of chloroform are supplied by means of the syringe. Thus, since forty minims of chloroform produce about forty-five cubic inches of vapour, the atmosphere in the bag contains $4\frac{1}{2}$ per cent. of chloroform-vapour. Of course, the per-centage is determined at will by the amount of chloroform supplied.

When sufficient of the atmosphere has been thus prepared the bag is detached from the metallic box, and the mouth-piece applied. It is then suspended in a convenient position from the collar of the administrator's coat. The position of administrator and patient is seen in the engraving.

In commencing the inhalation free air is introduced by an aperture (near the face-piece), which can be gradually closed as the patient becomes accustomed to the vapour.

I consider this to be the safest method of all for the administration of chloroform. Mr. Clover, in a letter to myself, states, "I have found my inhaler produce the anæsthesia more uniformly than I have been able to effect by any other means. Patients very rarely cough or make any manifestation of the vapour being too pungent. A large majority of the patients are prepared for the commencement of the operation in less than six minutes, and they certainly recover from the effects of chloroform more readily, and with less sickness and prostration than I have observed when I did not make use of the inhaler."

For myself, speaking theoretically, I believe that this means obviates the most urgent objection to chloroform-administration, and is especially useful when patients are assembled together ready to be operated on one after the other. The most potent objections to it are the somewhat cumbrousness

Fig. 11.



Mr. Clover's Apparatus.

of the reservoir, the necessity of employing some little time in making the mechanical arrangements for the production of the atmosphere, and, lastly, the expensiveness of the apparatus. Though of great value to those who are accustomed to administer chloroform, it is scarcely to be expected that every practitioner would provide himself with an apparatus of this sort.

Dr. Snow's apparatus.—The essentials are a metallic vessel

Fig. 12.



Snow's Inhaler.

Perpendicular Section of Inhaler.

a. Outer case for water-bath.
b. Cylindrical vessel into which the chloroform is put; it is lined with a coil of bibulous paper up to the point *c*.
d. Cylindrical frame which screws into *b*; it has apertures at the top for the admission of air, and its lower two thirds are covered with two coils of bibulous paper, which touch the bottom of the vessel *b*, except where the notches *e* are cut in it.
f. Elastic tube. *g.* Face-piece. *h.* Inspiratory valve.
i. Expiratory valve; the dotted lines indicate the position of the valve when turned aside for the admission of air not charged with vapour.

in which chloroform is contained, and through which air passes, thus carrying the chloroform-vapour along with it; a tube

which conveys a mixture of chloroform and air to the face-piece; and a flexible mask, fitting over both nose and mouth.

The vessel containing the chloroform is a metallic cylinder, in which are four stout wires descending nearly to the bottom. These are removable, and around them are two coils of blotting-paper, cut (after being tied upon the wires) into four slips. The upper part of the cylinder is perforated with holes for the admission of air, and the exit tube is attached to the top, the framework on which the blotting-paper is tied forming a continuation with it.

Thus, when air is drawn through the tube a number of currents pass through the apertures in the course of the arrows, over the blotting-paper moistened with chloroform, and then enter the exit tube. Hence the air which is inspired from the tube becomes impregnated with chloroform, the certainty of sufficient dilution being provided for by the free perforation of the plate through which it enters. But Dr. Snow, considering that the evaporation of chloroform gave rise to cold, whereby the further evaporation was impeded, adopted a means for surrounding his chloroform-containing cylinder with a body which should supply a sufficient amount of heat. The metallic cylinder was therefore surrounded with a stratum of water (of ordinary temperature) contained in another cylinder, an arrangement like that of a glue-pot.

The tube carrying the vapour is about a foot long; its diameter is about three quarters of an inch, so that it may permit of the passage of as much atmosphere as the patient can possibly breathe. Its length and flexibility allow the instrument to be turned anywhere out of the operator's way.

The *face-piece* invented by Dr. Francis Sibson is made of pliant material (leather or sheet lead). It is provided with two valves, one at its lower part, *i. e.* at the summit of the tube carrying the chloroformed-air, which allows the vapour to enter, but prevents the patient in expiration forcing air back again down the tube. Another valve is provided, which is made to cover an aperture in the front part of the face-piece. This is made movable, so as wholly or partially to close the aperture or to be turned away from it altogether. When it closes it it is a perfect expiratory valve, thrown forwards in expiration, and allowing the current to escape,

but sucked inwards in inspiration, and thus permitting only the entry of chloroformed-air through the other (inspiratory) valve.

This face-piece is certainly the best mechanical arrangement for conveying the vapour to the patient.

Mode of using the inhaler.—The interspace between the metallic cylinders being kept supplied with cold water, two or two and a half fluid drachms of chloroform are poured through the apertures of the cylinder. The liquid partly remains at the bottom, partly is absorbed by the blotting-paper coiled in the interior. The face-piece is then applied to the patient, its expiratory valve being so turned from its aperture as to allow an unimpeded entrance of air. Thus, the patient breathes the chloroformed air through the afferent tube and pure air through the opening of the face-piece. The valve of the latter is, after the patient has breathed a few times, so turned as partially to cover the aperture. The direct entrance of air being thus impeded, more of the chloroformed air is breathed; at last the valve is made to cover the aperture entirely and only chloroformed air is inspired. The mechanical arrangement is such that air at 60° will take up between 5 and 6 per cent. of vapour. After the first supply of chloroform has been dissipated more may be poured through the apertures of the cylinders; and thus, with occasional intermissions in the administration, the state of insensibility may be kept up. A glass tube from the interior of the inhaler passing to the outside enables one to see when the chloroform is exhausted.

Dr. Snow's instrument has certainly proved of immense value in regulating and methodising the administration of chloroform. There are, however, in my opinion, certain objections to it. Its water-bath makes it heavy and cumbrous; its long flexible tube is often in the way. It does not provide at the early stage a sufficiency of dilution to make the patient take kindly to the vapour and to prevent the occurrence of spasm or cough, and, lastly, the general proportion which it supplies (5—6 per cent.) is too high.

Several other forms of inhaler have been designed, all having arrangements for duly diluting and, as occasion might require, increasing the proportion of chloroform. Among the most efficient are Mr. Armstrong Todd's and Mr. Weiss's.

SECOND PRINCIPLE.—*The Administration of a gradually in-*

creasing Proportion of Chloroform (see Chapter IX).—I have stated the circumstances which tend to prove that the system will gradually become accustomed to a proportion of chloroform which it would resist at the outset. Mr. Clover's apparatus is supplied with a means whereby the early inspirations are made to be of an extreme dilution; his arrangement is in every respect perfect. Dr. Snow's inhaler, I consider, does not perfectly ensure a sufficient dilution at the outset. Coughing and resistance are common; the smell of the chloroform is strong and nauseating.

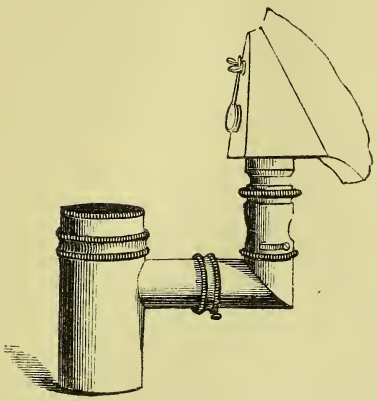
Some of the indications of a progressive tolerance of chloroform are so evident as to admit of no dispute. There is dislike to the vapour; patients will endeavour to force the inhaler away with the hands; they cannot be persuaded to breath calmly and quietly; they may show signs of spasm of the glottis, or may cough and make forcible expirations. Sometimes there is muscular struggling, half involuntary, half voluntary—a sign of intolerance, because when the administration is conducted in a progressive manner it does not occur. After a while increase in the proportion of chloroform no longer causes coughing, &c.—no longer gives rise to any sign of resistance.

My own practice is to administer at the commencement so slight a proportion of chloroform that the patient shall scarcely taste it; thus, the timid patient will be convinced that the process will not be unpleasant, and will not resist a proceeding from which he obtains no discomfort. After a few inhalations the proportion is slightly increased; the irritability of the glottis is so gradually deadened that coughing is not produced. The proportion is augmented as the patient will bear it; thus, the voluntary element in the struggling no longer obtains, the involuntary is reduced to a mere tremor, which indicates the time of severance from the functions of motion and sensation;* the whole symptoms assimilate to those of natural sleep. This free dilution and gradual increase of proportion can be attained definitely and satisfactorily only by due mechanical means.

The Author's Inhaler.—The great desideratum in an instrument for the administration of chloroform seems to be a plentiful supply of air, with a means for gradually increasing the

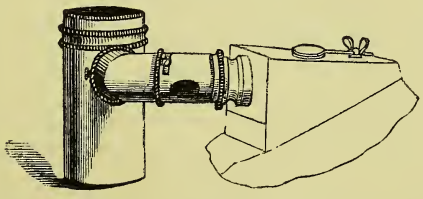
* See page 29.

FIG. 13.



Author's Inhaler, as adapted to the sitting position.

FIG. 14.



* Author's Inhaler, as adapted to the recumbent position.

proportion of chloroform; advantages which should be combined with this principle are simplicity, compactness, and portability, with such an arrangement that the instrument may at any time be turned out of the operator's way.

The *receptacle for the chloroform* is a small metallic cylinder; its height about three inches, its diameter about an inch and a half. It is filled with blotting-paper, loosely crumpled, or, what is better, a rolled piece of lint; at the top it is provided with a freely perforated plate, for the

* The Inhaler is made by Matthews, of Portugal Street.

admission of air and for the introduction of liquid chloroform. An exit tube passes at right angles from this receptacle, it being attached a little above the centre, so that a cup may be kept for the retention of any liquid chloroform which may be more than sufficient to moisten the blotting-paper or lint. Thus arranged, a direct current of air in inspiration passes through the apertures over the chloroform, and of course carries the vapour along with it.

The next requisite was to supply an equality of temperature. I found this object fulfilled sufficiently for all practical purposes by surrounding the metallic cylinder with a stratum of gutta percha. I found that a cylinder of equal size with that of Dr. Snow's cylinder, and surrounded with gutta percha as Dr. Snow's is with water, allowed even a greater per-centage of vapour to be given off than the latter did. Thus, in my experiments, after twenty inspirations in case of the cylinder surrounded with water, 30·4 cubic inches of vapour passed; in case of the cylinder surrounded with gutta percha 36·4 cubic inches passed.

After forty inspirations 54·2 cubic inches were given off by Snow's arrangement; 57·5 by the other.*

But, as I have before said, the difficulty is not so much in keeping up this high proportion as in preserving it sufficiently low.† I fulfilled the indication of diminishing the proportion by reducing the cylinder in size and bulk, and I was led to consider that the value of the gutta percha was not so much to keep the chloroform warm, as it were, but rather to prevent the metallic surface getting too warm from being held in a hot hand.

The tube conveying the mixture of chloroform and air.—It was thought much more convenient to abolish the long flexible tube. The exigencies of mobility were to be provided for; a very simple arrangement accomplished this. The exit tube was again bent at a right angle before ending at the mouth-piece. Thus the instrument was adapted to a patient in the sitting position, and the tube being freely movable at the place of adaptation of the mouth-piece, the cylinder could be turned to the right or left, as required. To make the whole instrument adapted to the recumbent position it was only ne-

* 'London Med. Review' and 'Med. Times.'

† See page 23.

cessary to make provision for a rotatory movement in the horizontal part of the exit tube. Thus, the chloroform-containing cylinder could be always retained upright. There was no necessity for a flexible tube, for, by the double movement of the receptacle on the exit tube, and of this tube on the face-piece, any position was provided for—the receptacle was always preserved upright, so that no chloroform could be spilled, and any movement of the patient, however brisk, could be followed in a moment.

Means for ensuring perfect dilution with air.—In that part of the tube which terminated in the face-piece I caused to be introduced an arrangement by which a supply of air could be turned on or cut off at pleasure. The tube here is double, an external rotating upon an internal; both are perforated, front and back. Thus, in one position air enters freely; by slightly turning the outer tube the apertures are partially closed, and by turning it still more they are covered completely; the unperforated portions of one tube cover the perforations of the other.

The *face-piece* is the same as that described as Dr. Sibson's, but it freely turns upon the tube of the inhaler.

Mode of use.—The receptacle being supplied with blotting-paper or lint, and a little piece being also laid along the horizontal part of the tube, so as to act as a syphon, a drachm and a half of chloroform is poured into it. This quantity is usually sufficient, as there is so little waste. The outer movable tube near the face-piece is so turned that the holes in it are coincident with the holes of the inside tube; consequently, unimpeded currents of air enter. Moreover, the valve of the face-piece is turned away from its aperture. The patient being now allowed to inhale, breathes so much atmospheric air that the taste of chloroform barely reaches him. The outer tube is then turned so as to cut off in a slight degree the entrance of air, and this is done every two or three inspirations, until, the apertures being closed, no air enters by these channels. Still, the aperture of the face-piece allows the entry of air. This expiratory valve being made gradually to cover its aperture, the patient breathes a sufficient proportion of chloroform perfectly to induce anæsthesia.

The process is thus a gradual one from the beginning until such time as the patient is able to breathe an atmosphere of 5 per cent. There is no cough, no struggling, no resistance,

but the patient succumbs to the chloroform-sleep gradually and imperceptibly.

I use face-pieces of two sizes, one for adults, the other for children above seven years. For those under seven I do not use an inhaler, for I am quite convinced that the crying and irregular breathing of children of tender age annul its value; and it is in cases of young children that chloroform attains its maximum of safety.

An impromptu inhaler.—It is sometimes necessary to give chloroform at a time when the apparatus is not at hand. I believe the following to be the best plan of procedure:—Procure an oblong piece of brown paper, about eighteen inches long by twelve wide, or in default of this a newspaper folded in three; place upon it a pocket-handkerchief smoothed out, and retain it by two or three pins; then roll the paper so as to form a hollow cylinder of about four inches in diameter, which will thus be lined by the handkerchief. One extremity of the cylinder can be applied so as to cover the nose and mouth of the patient. Chloroform is poured upon the handkerchief. Air freely enters the hollow of the cylinder, and thus provides for the dilution.

This instrument is something like that which has proved very useful in the "Service de Santé de la Marine" of France.*

CHAPTER XV.

PRACTICAL RULES FOR THE ADMINISTRATION OF CHLOROFORM.

Whatever inhaler be adopted, or whatever means be employed in the administration of chloroform, care and caution are necessary. On no account should it be given in the absence of a medical man, and it is never desirable that a patient

* 'De l'Emploi Méthodique des Anésthesiques, &c.; à l'aide de l'appareil règlementaire dans le service de Santé de la Marine, par Ernest Berchon.' Paris, Masson, 1861.

should administer it to himself. Under the eye of the doctor, with every requisite for producing a very sufficient dilution, the patient, in a confinement, for example, may be allowed to apply it on the occurrence of pain. This is the only exception.

The administrator should be experienced. It has been in some cases a custom to intrust the chloroform to a young dresser—one who might be more anxious to watch the progress of the operation than the stage of the narcosis. This is a state of things to be deprecated, and several hospital committees have acted wisely in appointing a Chloroformist—a measure which is not of less value to the operating surgeon than it is of benefit to the patient. One who administers chloroform in any case should confine himself exclusively to the task he has undertaken, and should constantly mark the symptoms. Those who are not much accustomed to it may err on one of two sides. They may be fearful of giving too much, and so may incompletely abolish the suffering, or they may plunge the patient into too profound a coma.

All hurry should be avoided. I have before called attention to those symptoms whereby Nature has asserted her repugnance to the administration of strong atmospheres. The gradual, the progressive administration entails but very little sacrifice of time. Six minutes are amply sufficient to induce the anæsthesia; but pushing the administration at the early stages produces, not only repugnance, but also danger.

It may be in a case here and there that a long period elapses before the symptoms of true narcosis occur. The period of excitement may be prolonged. It is precisely in these cases that the greatest care is required; these have manifested the greatest danger. I have frequently seen any attempt at forcing the inhalation in these followed by symptoms of deep coma or almost collapse. . In fact, this is a frequent history of those cases which have manifested danger.*

A short time ago I heard that during the use of my own inhaler at a country hospital symptoms of threatened death occurred. I wrote to the house-surgeon my views with respect to danger from chloroform, and the different forms of death. In reply, he gave me an account of how the symptoms of danger

* See pp. 68 & 73.

occurred. "The alarming symptoms," he wrote, "did not come on during the time that your apparatus was used, but subsequently, when, to expedite the anæsthesia, I used a cone of lint instead." There was a difficulty in inducing the narcotism; the patient long resisted the influence. In a case of this sort my strong advice is that, regardless of anything, the inhalation should be slowly continued, never suddenly pushed. It is better to put off the administration and the operation than to force the former against signs of intolerance.

An administrator of chloroform accepts a certain amount of responsibility. The whole responsibility I consider to be divided equally between the surgeon who counsels the administration for the performance of the operation and the administrator who deals with an agent the use of which demands care and caution.

At the risk of recapitulation, I think it right to state here certain conclusions which I have formed with respect to the immediate cause of death, as they have some reference to this question of responsibility. Death in the human subject may occur—(1) By spasm of the heart. In this case the heart is found after death contracted like a solid ball. This form of death is rare. I believe it to be an aggravation of that influence upon the sympathetic nerves which, in the exhibition of narcotics, causes contraction of the arteries and capillaries.* (2) By paralysis of the heart—paralysis of the sympathetic. In such instances in animals we have found a sudden dilatation of the walls of the arteries and capillaries. This is the usual form of death from chloroform in man, and it is this form which is aggravated and even caused by emotional influences —by fear and terror, by tendency to faintness, and so-called idiosyncrasy. Nothing more than this points out how necessary it is to proceed gradually and to induce confidence and calm. It is obvious that, whatever care be taken in the administration, danger may occur, because danger and even death will occur from emotional causes when chloroform is not in the question.† Only, if the administrator have used all reasonable care, he will have done all in his power to avert the tendency. In any medico-legal investigation when this form of death has occurred, particularly when (as has usually been the case) it has been early in the administration, the consideration

* See page 60. † See page 12.

of the influence of emotion should have its due weight. (3) By palsy of respiration—by suffocation. Such has been observed in instances of congestion of the lungs. (4). By coma—by the profound action of chloroform. This is the only case in which death may be said to be purely and simply by chloroform. The others are rather accidents in the course of the action than the direct action itself. It is a form of death which is not common in the human subject; but it rather indicates that narcosis (for reasons which may be rendered necessary by the case—in instances requiring muscular resolution for example) has been pushed too far.

General rules.—I. Examine the condition of the patient's health. I have said how few things preclude the administration;* but every case requires care, and every case may require a treatment special and peculiar. A hasty administration, regardless of coincident circumstances, may be safe in the great majority of cases; but, obviously, the more we know about the patient the better. It is better, not only for the purpose of excluding certain cases wherein organic diseases would prove predisposing causes of danger, but also for the purpose of regulating the steps of the administration. For example, one should, in those of feeble heart, be especially careful to administer dilute atmospheres; in those of impeded respiration any sign of mal-aëration should be watched. The examination is of especial importance when chloroform is administered for the performance of such slight operations as tooth-extractions, simple incisions, &c.

II. Be careful that the patient has not had food for about four hours. If in any case it is necessary to relax this rule, take especial care to avoid haste in administration, and if vomiting be induced encourage it before proceeding further. The influence of the progress of digestion in enhancing the danger of chloroform has been before noticed. I have always thought that a tablespoonful of brandy in water, or a couple of glasses of wine (sherry or champagne) have been of service. It may be that the slight stimulus has dissipated some of the mental apprehension, but I have thought that the value has been something more. In animals I have found, not only that alcohol has diminished the tendency of chloroform to prove fatal, but it has excited the circulation when feeble.

* See Ch. VIII.

III. Regulate the position of the patient. The best is the recumbent, but in cases of dentistry and of certain operations about the face there is a necessity for the sitting posture to be observed. The rule should be, let the patient observe the recumbent posture unless the exigencies of the operation point otherwise. The tendency to syncope is greater in the erect and sitting position than it is when the body is horizontal. The pulse in the latter condition is more slow and quiet; thus, though it may be seventy in the former position, it will frequently sink to sixty-five, or even sixty, in the latter. The reason, therefore, that the recumbent posture is to be preferred is that the circulation is more steady and the tendency to faintness is less.

Whatever be the posture, the rule of Dr. Richardson is most valuable. Let the patient retain the selected position for three or four minutes before inhalation.*

Remove the neck-cloth and any clothing which interferes with the free play of the chest in respiration.

IV. Reassure the patient. I have sufficiently pointed out the necessity of overcoming fear. "A few gentle words or a brief conversation, enticing the mind to the consideration of other subjects than danger, or a chance of danger, is invariably a wise and safe policy."†

V. Commence the inhalation gradually. Use no force if it can possibly be avoided. Persuasion is better than restraint. The value of the gradually progressive administration has been sufficiently shown in former pages. Recollect that any sudden increase in the strength of the vapour can produce sudden syncope.

The administrator should observe the countenance, the respiration, and the pulse. There has been too much dispute as to which should receive most attention. Some writers have urged attention to the pulse to the exclusion of the breathing, others *vice versâ*. The truth is, to my mind, that all the signs should receive attentino—none more than the others.

The pulse of itself gives no indication of the stage of the narcosis, but any feebleness or hesitation in it is a sign that the administration should be intermitted.

* 'Lectures on the Teeth,' p. 252.
† Dr. Richardson.

The administrator should, it has been advised,* keep one hand free for careful observation of the pulse. My own practice is, as I hold the inhaler in one hand, to keep the other upon a branch of the temporal artery. It is easily felt, and thus the pulse is constantly under observation.

VI. Continue the administration until the necessary stage of narcosis is arrived at. These stages I have divided into three. In the *first stage*—SOPOR (perversion of sensibility) there is no distinct sign of demarcation, but it is measured by the patient's own expression. There is apparently a light sleep, a dreamy half-consciousness, frequently a knowledge of what is being done, and yet an almost complete loss of sensation. For simple incisions, the removal of a single tooth, division of tendons, in cases wherein pain is to be relieved, neuralgia, dysmenorrhœa, and even in natural labour, this stage need not be overpassed.

In the *second stage*—STUPOR (abolition of sensibility)—there is absence of all consciousness, and a state of quietude. The signs which indicate that this stage has arrived are—(1) The occurrence and subsidence of an involuntary tremor of the muscles in the course of the administration. Usually this is the less violent the more gradually the vapour is administered. (2) The absence of winking when the eyelid is lifted up and the edge of it is touched. (3) The absence of any expression of pain when the skin is pinched or pricked. I believe that the first of these signs is the most reliable, but they should be taken conjointly. This step is the one which it is usually necessary to induce for the performance of a surgical operation.

In the *third stage*—STERTOR (muscular relaxation)—the signs are snoring respiration and complete flaccidity of muscle. A limb, being lifted, gives no sense of resistance; usually the pupils are dilated. This stage is rendered necessary when dislocations have to be reduced, when relaxation of the muscles is rendered necessary; in operations for hernia, in certain operations in parts which are long in parting with their sensibility (the perinæum, for example), &c.

Whatever may be the stage rendered necessary, the inhalation should be steadily persisted in till this is arrived at. Only if in the course of the administration the patient makes two or three deep inspirations in succession, the chloroform should be temporarily removed. If stertor occur, the inhala-

* "Report of Committee on Chloroform," Royal Med. and Chir. Soc. abstract.

tion should be suspended; and in passing from the second stage to the third an endeavour should be made to intermit it just before the occurrence of stertor, for the symptoms of anæsthesia become more profound for a short time after the inhalation is suspended. The residual amount of chloroform in the lungs, as was shown by Dr. Snow and Prof. Sédillot, becomes absorbed, and thus deepens the existing narcotism.

VII. When the necessary stage is arrived at allow the patient to breathe pure air. If the operation be of short duration no reapplication of the chloroform will be necessary. Usually it has to be repeated at intervals. The proportion last breathed can be then again administered without any more free dilution. Again, there may be a few inspirations of air, and then a reapplication at intervals of thirty or forty seconds. Thus the necessary stage can be kept up for any length of time.

VIII. Do not be too anxious to reapply the chloroform towards the close of the operation, for frequently there will be a return to partial consciousness, although there remains a complete absence of pain.

IX. During the time of recovery from the effects of chloroform let the patient be as little disturbed as possible. A natural sleep is the best of sequelæ.

If vomiting occur it is better at first not to check it. If it become persistent a little brandy and soda water constitute the best remedy.

Hysteria, epilepsy, and a sort of catalepsy, have, in a few instances, occurred; these are best treated as ordinary cases; indeed, they may be considered as indirect effects, not due to the chloroform.

CHAPTER XVI.

ON ANÆSTHETIC MIXTURES.

From our consideration of the various volatile agents capable of inducing narcosis some data as to their relative efficacy and relative danger may be gathered.

Ether and alcohol, in the narcosis which they produce, do not necessarily depress the power of the heart. Chloroform and hydrocyanic acid have a certain effect in depressing the heart's action.

A condition of anæsthesia does not imply any diminution of the normal circulating force—it may exist even with an increase of it. Chloroform in small doses, even during perfect narcosis, need not depress the power of the heart, but it is capable of doing so, and that under conditions which are not under absolute control.

Whilst, therefore, we accept chloroform as the most efficacious and convenient agent we know of in producing abolition of pain and of sensation, there are many reasons to hope that an agent may yet be discovered which, though perfect in its power of abolishing suffering, may yet exercise no depressing influence upon the heart.

We have considered that the means to be adopted to diminish and nearly abolish the danger of chloroform are—(1) free dilution, (2) gradual administration.

Certain anæsthetic mixtures which have been proposed possess a further advantage, viz., the superadded effect of a stimulant upon the heart.

It may be said, once for all, that the objections to the use of anæsthetic mixtures are—(1) the length of time which their administration occupies; (2) the consequent probability of inflicting pain, the abolition of sensation being insufficient.

The cases in which anæsthetic mixtures are most applicable are—(1) those in which heightened local insensibility (pain) only has to be produced, without any more profound effect, such as obliteration of consciousness; (2) (according to the Chloroform Committee) when deep or prolonged anæsthesia is to be induced. I would add (3), that especially the ether-

mixture might be used in cases in which complete muscular relaxation is required.

The mixtures recommended by the Committee on Chloroform are the following:

Mixture A.	Alcohol . . .	1 part.
	Chloroform . .	2 parts.
	Ether	3 „
Mixture B.	Chloroform . .	1 part.
	Ether	4 parts.
Mixture C.	Chloroform . .	1 part.
	Ether	2 parts.

As I have said before, each of these mixtures ensure a more complete dilution than when chloroform is employed alone. Supposing chloroform alone were used, and an atmosphere containing 5 per cent. were breathed, if the anæsthetic mixture B were employed, probably only about 1 per cent. (of chloroform) would be breathed. For this rough estimate it may be considered that ether has about the same rate of evaporation as chloroform. Practically this is not precisely so, for the rapidity of evaporation of ether is greater than that of chloroform—another circumstance favoring the dilution.

The committee observed the relative rates of evaporation by placing a known quantity on a cloth, and exposing it to the air.

The per-centage lost after exposure was, for three minutes—ether, 89 parts; chloroform, 75 parts: fifteen minutes—ether, 93 parts; chloroform, 85 parts.

It must be recollected that though, at first, the dilution of chloroform-vapour is thus complete, after some time the less vaporizable chloroform remains behind, and therefore the proportion inspired increases.

"The first of these mixtures (A) was proposed several years ago, and employed by Dr. Harley.

"The second and third are mixtures which, it is believed, have been extensively used in America.

"It was found that the physiological effects of the mixture B were very similar to that of simple ether; an animal might inhale it for forty or fifty minutes, even in a tolerably strong form (15 per cent.), without destroying life.

"The mixture, however, was open to the same objections as ether itself, the chief of which was the slowness of its opera-

tion. The length of time necessary to produce anæsthesia with it was so great as practically to preclude its employment.

"When a sufficient quantity of this mixture was given to destroy life the respiration was observed to cease some time before the heart's action. The force of the cardiac beat, moreover, as indicated by the hæmadynamometer, was well maintained throughout the period of anæsthesia.

"The mixtures A and C were very similar to each other in their action. This quite accorded with the fact that the proportion of chloroform was the same in both. The mode of their action, moreover, was intermediate between that of ether and that of chloroform.

"It was found in the human subject, as well as in animals, that insensibility might be induced by means of them with sufficient rapidity; that is to say, in four to eight minutes in animals, and in from ten to fifteen minutes in man.

"And, further, it was ascertained, in animals, that inhalation of the vapour in a strong form might be continued for thirty or forty minutes without destroying life. Indeed, it was only upon employing a concentrated form of the vapour, and after prolonged endurance of its action, that death ensued.

"In nearly all the experiments in which the animal was at length destroyed the respiration ceased some little time before the heart's action; and in nearly all, including those in which a strong vapour had been employed, there were temporary suspensions of the respiration, followed by recovery, such as have been described as produced by the inhalation of diluted chloroform-vapour.

"These mixtures exercised a much less depressing effect upon the action of the heart than chloroform alone. In this respect, again, the mixtures appeared to combine the qualities both of ether and of chloroform; it being clear that, at the same degree of insensibility, the depression of the heart's action was less with either mixture (A or C) than with chloroform.

"These considerations tend to establish the fact that a mixture of ether and chloroform (such as A or C) is as effective as pure chloroform, and a safer agent when deep and prolonged anæsthesia is to be induced, whilst at the same time it is sufficiently rapid in its operation to be convenient for general use.

"It is quite possible that at some future time an anæsthetic may be discovered which will fulfil the required conditions yet more perfectly than either of these mixtures. In the mean

time the committee suggests that both of them should be more extensively tried than they have hitherto been in this country. Of the two mixtures, preference is, in the opinion of the committee, due to A, on account of the uniform blending of the ether and chloroform when combined with alcohol, and probably the more equable escape of the constituents in vapour. The alcohol which it contains probably stimulates and sustains the action of the heart.

"The mixtures A and C have been tried, at the request of the committee, in about seventy cases in the London hospitals, and the evidence of this limited experience tends to show that they may be given with safety and with complete effect, although they take a longer time than chloroform (ten to fifteen minutes) to procure anæsthesia."*

In my own experiments I have found that alcohol had had the greatest effect in sustaining the heart's action during the influence of chloroform. I can particularly recollect one instance in which alcohol, having been administered in vapour to a frog, it was impossible to cause death by any strength of chloroform-vapour. I certainly think that a dilution of chloroform with alcohol is advisable in many instances, and I am quite sure that the administration by the stomach of a little alcoholic stimulant acts beneficially.

It has been, under certain circumstances, the custom to add flavouring ingredients to anæsthetic mixtures. Dr. Townley uses the following *anodyne mixture*:

"Alcohol, two ounces; one drachm of aromatic tincture; with sufficient chloroform added short of the production of a turbid state of the fluid." The aromatic tincture is prepared as follows:—"One drachm of nutmegs; two drachms of cloves; pterocarp chips, a drachm and a half; water, four ounces; alcohol, five ounces; mix."

Dr. Townley instructs his patients to breathe rapidly this anodyne mixture from an inhaler which admits a free dilution with air. The gist of his practice is "small doses." The "repeated but interrupted impressions made upon the nervous system" signify nothing. The chloroform is of such considerable dilution that it requires the energetic breathing mentioned to produce any of its effect. That effect, however, is produced by absorption, not by sudden impressions upon the nervous

* "Report of Committee," 'Med.-Chir. Trans.,' vol. xlvii, pp. 339—343.

system. Dr. Townley has done much good, for he has shown that in painful affections (labour, *par excellence*) it is not necessary to produce unconsciousness, but that the early stage of the action of chloroform may be made available—that stage in which its influence is that of a stimulant, not that of a narcotic.*

I have before said how hazardous I consider it to administer chloroform upon a handkerchief, &c. If people cling to the use of such means, let them use these mixtures, not undiluted chloroform.

CHAPTER XVII.

CHLOROFORM IN SURGERY.

The causes for which chloroform-inhalations are employed in surgery may be briefly classified under the following heads: —1. Relief of pain. 2. Reduction of spasm. 3. Production of quietude for the application of surgical apparatus. 4. Performance of surgical operations. 5. Production of muscular relaxation.

Cases are very rare indeed in which chloroform is contra-indicated when any of the above conditions have to be fulfilled. The states of disease under which its employment is dangerous, and the various degrees of the danger, have been discussed before; but there are certain circumstances which come immediately before us in the determination of its value in Surgery.

The question occurs, whether chloroform should be administered during the primary shock of an injury? My own opinion is that the answer to this question should be rather relative than positive. The greater the amount of shock the greater chance of syncope and the greater danger from chloroform. Another consideration favours the solution of the

* 'Parturition without Pain or Loss of Consciousness,' by James Townley, M.R.C.P.E., F.R.C.S., &c. Third edition. London, 1863.

question; for the greater the shock the less is the appreciation of pain, and, consequently, so much the less is the necessity for the administration of chloroform. The system of the injured man is suddenly depressed by the injury—can he bear the superadded depression produced by the chloroform?

The idea that pain has any effect in stimulating the vital powers, and that, therefore, no attempt to mitigate its severity should be attempted in cases like these is, no doubt, an erroneous one; but the pain is greatly mitigated by the state of shock, and the subsequent depression from the surgical interference alone is but slight. Each case must be judged upon its own merits. If there is a complete state of shock chloroform should not be used; if it be incomplete, and the appreciation of pain be great, it should be employed, and then not to the extent of inducing narcotism, of running the risk of producing vomiting, but to the first stage only—to benumb sensation, not to annul it.

Chloroform in military practice.—In the great bulk of the operations rendered necessary during war, in secondary operations, after the shock has subsided the influence of chloroform is ureservedly for good. In primary operations, on the battle-field, for example, it should be employed with the greatest caution. Above all, rather than it should be used hurriedly it should not be used at all. In every case the quantity of chloroform administered should be inversely as the shock of the accident, and no wounded man should be allowed to inhale an unknown proportion from a folded rag. The security of a free dilution should be at least guaranteed, and this should be administered sparingly, not to the extent of inducing absolute insensibility.

In cases requiring *tracheotomy* or *laryngotomy* I consider that it is better to dispense with chloroform.* This is a question about which difference of opinion exists, but in reference to it I think the following considerations have most weight:—1. In an operation like this, inconsiderable as far as suffering is concerned, but yet all important as just determining between life and death, the mere pain of the necessary incision is not of much importance. 2. The state of dyspnœa which usually exists has probably produced a benumbing of the senses and diminished appreciation of pain. Dr. Hillier

* See Henry Smith in 'Med. Times,' March 2nd, 1861.

relates a case of a gentleman who, when tracheotomy was proposed for him, begged for chloroform, and it was administered; yet when he recovered he declared that at the time before the chloroform had been administered his state of dyspnœa had induced in him a condition wherein he was not only incapable of coherently expressing his feelings, but even of feeling anything.*

3. The danger of by any chance producing irritation of the glottis, or any suffocative cough, is to be avoided. Cases in which dangerous symptoms have occurred when chloroform has been administered for the performance of tracheotomy have not been infrequent. Mr. Fergusson speaks of two patients whose lives he saw placed in jeopardy by chloroform, and one of these was about to undergo tracheotomy for disease of the larynx.

In a case occurring at Bath, to a boy aged seven, to whom a very diluted atmosphere was administered, the tube was scarcely within the opening in the trachea when death occurred.*

I have here recorded only my own personal opinion in this matter. The Committee of the Medical and Chirurgical Society has come to an opposite conclusion, viz., that "in all cases requiring laryngotomy and tracheotomy the anæsthetic may be employed with safety and advantage."†

In cases of operation for cleft palate, and such manipulations as require co-operation on the part of the patient, chloroform should be dispensed with or else given very sparingly. A few whiffs may be permitted, so that the local sensibility may be benumbed. A gargle of iced water is the best local anæsthetic during the intervals of the operation.

I also consider that the employment of chloroform is unadvisable in some operations on the eye, to be mentioned hereafter.

These cases in which chloroform is of doubtful benefit detract but a very little from its character as a universal boon.

It is sufficient to induce the FIRST STAGE of chloroform-narcotism in the following cases. First, in those in which the object is to relieve pain; heightened sensibility (pain) is destroyed in the course of anæsthesia before common sensibility. Hence,

* 'Med. Times,' March 9th, 1861.

† "Report," 'Proceedings of Med.-Chir. Soc.,' vol. iv, p. 384.

in these cases, the mental faculties need be disturbed scarcely at all. Thus, administered at due intervals, it has a wonderful effect in suppressing the pain of neuralgia, of suppuration (during the active suffering of a certain stage of a mammary abscess, for example), and of ulceration. Nothing gives so much relief for the racking pain of cancer.*

Chloroform administered to this degree is very useful to prevent the pain caused by the dressing of wounds; the way in which it thus diminishes the irritability of patients and lessens the poignancy of subsequent pain is very marked. Since, also, the skin loses its sensibility early in the course of the action of chloroform, even before the loss of consciousness, many operations of short duration may be done in this stage. Simple incisions—for opening an abscess, for example—may be made; small tumours may be excised. Simple cauterizations may be effected; tenotomy may be performed; muscular spasm being reduced, catheterism may be sometimes practised in this stage; foreign bodies may be removed from the ear or nose; tonsils excised; polypi removed from the air-passages. "In operations upon the soft palate, fauces, pharynx, and posterior nares, if sudden or severe hæmorrhage is likely to occur, it is not advisable to induce deep insensibility."‡ Mr. Mason tells me that on one occasion, when Mr. Fergusson operated on a little boy about ten years old for simple evulsion of a polypus, chloroform being administered, the polypus slipped back into the glottis, and gave rise to a condition of much anxiety.

The SECOND STAGE is to be induced when quietude is necessary as well as complete absence of pain. When splints have to be applied, especially in the case of sensitive subjects, chloroform is invaluable.

In cases where it is administered for the performance of operations I consider it best that at first the patient should not be excited by the presence of friends, or even of those who have come to aid in the operation. The administrator, and one other person only, should be with the patient in the early stage. So in hospital practice I consider that the inhalation should be commenced in the ward or in a room near the operating theatre, and only completed in the presence of observers.

* 'Brit. Med. Journal,' May 25th, 1861.
† "Report of Committee," loc. cit.

This stage of chloroform-narcotism is suitable for most of the major operations. Few hints can be added to those already given; each class of operation requires in some way peculiar treatment, but in most the indications are sufficiently obvious.

In the *treatment of deformities* the value of chloroform is now unquestioned. A strange and interesting case may be here cited, in which chloroform accomplished a cure:

A girl, about nineteen years old, was admitted into King's College Hospital with supposed wry neck. To speak more correctly, her head rested upon her left shoulder. She had been in this condition nearly a twelvemonth; the symptoms were attributed to hysteria. Whatever the diagnosis, the deformity remained. She was taken to the operating-theatre, and after chloroform had been administered Mr. Fergusson simply lifted her head round to its proper position. A bandage was applied, and she was sent off to bed. In a few days she was discharged perfectly well.

In *amputations* perfect anæsthesia must be induced, and continued till the last half dozen sutures are being applied to the flaps. Consciousness may then return without the pain of these few punctures being felt.

In *lithotomy* the process of bandaging should not be commenced till consciousness has been abolished.

In *removal of malignant tumours*, the anæsthesia being well kept up, the operator is enabled to search for any other parts implicated in the disease. Thus, the extermination of the latter has, no doubt, been rendered by the introduction of anæsthesia more hopeful.

Chloroform has shown, perhaps, its greatest value in permitting the performance of protracted operations which it would have been hopeless to attempt before the days of anæsthesia.

Operations for diseased bone.—There can be no doubt that many persons are now restored to health who in times past would have preferred to linger on with a hopeless disease rather than face the terrors of an operation. Limbs which would have been amputated are now saved by the removal of their diseased bone. There is no limit to the time during which a patient may be kept insensible during these operations; thus frequently the entire shaft of bones has been removed.

Excisions of joints.—In these cases it is not doubted that

chloroform is invaluable; they have grown with the growth of chloroform. Thus, the good done by the anæsthetic has been doubly manifest:—1. By substituting for amputation an operation intrinsically less dangerous. 2. By saving limbs instead of sacrificing them.

Lithotrity also has almost grown out of the practice of anæsthesia. Certainly difference of opinion has existed as to the value of the latter in such cases, but I consider it hardly admits of doubt for few would bear the frequent repetition of the painful process until the completion of the cure. "For my own part," Mr. Fergusson states, "I am opinion that there is not any department in practical surgery in which anæsthesia has been of more service than in this."* The objectors have urged that injury may be done by the lithotrite, the patient's sensations being abolished; but, as Mr. Erichsen has remarked, the best guide in the safe performance of the operation is constituted, not by the sensations of the patient, but by the sensations of the operator.†

Plastic operations have been rendered more practicable by the introduction of anæsthesia. Thus, no doubt, not only the appearance, but the physique, of the sufferer has been improved. In all these cases of protracted operations the chloroform should be occasionally left off until there is an expression of a faint appreciation of pain. Then it should be at once reapplied.

In operations upon the cranium chloroform may be used with impunity. It has no effect in producing turgescence of the brain, as many have believed.‡

Other operations suitable to this stage of narcosis, and which it is unnecessary to do more than mention, are removal of tumours, ligature of arteries, division of nerves, forcible movements of stiff joints,§ operations for stricture of urethra, operations upon the penis and scrotum,§ cauterizations, &c.

Chloroform in operations about the mouth.—The fears of those who expressed their opinion that anæsthesia could not be safely employed in operations which rendered it likely that blood might, in the state of insensibility, fall through the glottis, were certainly, at first sight, not unreasonable. Practice, however, has shown that, though blood may pass through the

* 'Pract. Surg.,' 3rd ed., p. 800.

† Vide 'Science and Art of Surgery,' 4th ed., p. 1112.

‡ See page 61.

§ In many cases more profound narcosis is necessary.

pharynx into the stomach, it very rarely passes through the glottis, and if by any chance a few drops get into the trachea they are instantly coughed up again. The reason of this is that the glottis is endowed with a long-persistent sensibility and irritability which it does not lose throughout the whole course of chloroform-narcotism.

The patient's head being inclined with the mouth downward, and the blood thus tilted out, very little is allowed even to get into the stomach. The Chloroform Committee has come to these conclusions:—"For all operations upon the jaws and teeth, the lips, cheeks, and tongue, the anæsthetic may be inhaled with ordinary safety. By care and good management the patient may be kept under its influence to the completion of the operation. In these cases blood, as it escapes, if not voided by the mouth, passes into the pharynx. If any small quantity finds its way through the larynx it is readily expelled by coughing."

The danger in these cases is more from the hæmorrhage induced by the operation than from the chloroform. Mr. Liston lost a patient from this cause. The operation was for a tumour of the upper jaw; the patient died upon the operating-table. Dr. Snow relates a case of death. Chloroform was given in this instance, but evidently had nothing to do with the fatal result for consciousness had returned; the man died from loss of blood.

It is very important, when an operation has to be performed in the cavity of the mouth, to desire the patient to inhale the chloroform with his mouth partially open. Otherwise in the state of anæsthesia there is such difficulty in overcoming the rigidity of the muscles of the jaws that even a lever can scarcely separate them wide enough for the ready performance of the operation. It is very unsafe to push the chloroform so as to produce relaxation of the muscles. M. Simonin* has noticed that contraction of the masseters occurs latest in the period of excitation of the muscular system, and persists longest. He says that whilst they are yet rigid the rest of the muscular system may be relaxed. These muscles receive their nerves from the medulla oblongata; if they be paralysed, the muscles of respiration share the paralysis; hence the danger of the sign

* 'Rev. des Soc. Savantes,' June 26th, 1863.

when these collapse. A small wedge of hard wood should be placed near at hand to aid in opening the mouth.

For prolonged operations in this region there has been a special difficulty in the administration. After the chloroform has been given in the usual way, and when the operator has begun his manipulations, it is impossible to keep up a continuous administration. The usual mode is to hold as near to the nose and open mouth as can be permitted, without inconvenience to the operator and his assistant, a hollow sponge or a cone of lint sprinkled with chloroform. Very often the attitude of the operating surgeon prevents the chloroform from coming to the patient, who thus awakens to the pain and to a sense of the hæmorrhage. I have frequently seen this distressing return to consciousness in the course of an operation for removal of the upper or lower jaw. By a modification of a method instituted by M. Faure, of Paris, I have been able to preserve the anæsthesia in cases of this sort without causing the slightest inconvenience to the operator. M. Faure introduced a plan for administering chloroform by the nostrils. He considered that if the vapour were conducted to the lung by one nostril, the other being patent to the air, sufficient dilution was guaranteed, and anæsthesia could always be induced. In practice, however, for the production of anæsthesia, this method has proved of far less value than the others; for the *maintenance* thereof it is very efficient. My own plan* has been as follows:— After anæsthesia has been induced in the usual manner, when the operator is just about to begin, his hands being in the way of the inhaler, and consequently the patient breathing air both by the nostrils and by the open mouth, I introduce up one of the nostrils an elastic tube which communicates with a vessel in which chloroform is freely vaporized. The other nostril is left open to the air, but if the symptoms indicate that a stronger vapour should be administered I press this nostril with my finger so as to close it; thus it becomes a valve to promote or retard dilution. I must add that I have found this method succeed most admirably. In the course of prolonged operations the anæsthesia has been kept up most perfectly till the end, and the elastic tube has enabled the administrator of chloroform to keep away all inconvenience from the operator.

* See 'Med. Times,' May 25th, 1861.

The practical details of applying this method will be treated in the chapter on "Chloroform in Dentistry."

Chloroform in ophthalmic operations.—Difference of opinion has existed with regard to the value of chloroform in these cases. It has been urged that in many the operation can be done with equal ease without it; that under its influence muscular spasm may, under certain circumstances, produce extrusion of the contents of the globe, and the possible vomiting may act in an equally baneful manner. Each case must be judged by itself. In children in whom operations upon the eyes have to be performed, it is invaluable. Resistance without it is certain, and unsteadiness of the eye is a frequent cause of failure. In adults, if there is sufficient self-control, the operation may be performed as well without chloroform as with it; and the pain of extraction of cataract, for example, is not of the violent nature of many operations upon the surface. Operations for ordinary extraction of cataract, some cases of iridectomy, incisions in the cornea, Mr. Hancock's operation, &c., may be performed without anæsthesia; but for the delicate operations which require stillness on the part of the patient, for those refinements which have brought ophthalmic surgery to its present delicate perfection, for the majority of cases of iridectomy, not only is chloroform necessary, but it has itself been the parent of these operations, which would have been simply impossible without it.

As my friend Mr. Francis Mason has noticed, chloroform is very valuable when one wants to examine the eyes of a patient with strumous ophthalmia. The photophobia is so great in these cases that there is frequently no getting the patient to open the eyes.

The *first stage* of narcotism is sufficient for certain operations upon the eyelids; for the extirpation of cysts, for incisions into abscesses, for the removal of little tumours, &c.

The *second stage* for the more extensive operations upon the lids, for ectropium and entropium, and other plastic operations, for cataract, iridectomy, &c., in ordinary cases.

In case of the operation for squint there is a point worth mentioning. One often finds, in operating under chloroform for *internal* strabismus, that after the division of the muscle the eye is slightly *everted*, but the parallelism is natural as soon as the effects of the chloroform pass away.

The *third stage* is required for amputation of the eyeball and

for those cases which demand absolute stillness on the part of the patient. Such are certain operations for the formation of artificial pupil, iriddesis, &c.

In all ophthalmic cases chloroform should be administered very gradually, and the rule as to abstinence from food before the inhalation should be strongly insisted on. A case of death occurred in a patient who was about to be operated on for glaucoma. The resistance was great; half an hour was taken up in getting the patient under the influence; vomiting occurred, and the anterior chamber became filled with blood. The man was a model of health. The lesson, to my mind, is that in such a case the inhalation should certainly not be forced; when there is such resistance it should be dispensed with.

A most important point in the management of these cases of operations upon the eye is to watch the period of semi-consciousness prior to complete recovery from the effects of chloroform. The patient is apt to lift his hand and rub the eye, and he may thus inflict a good deal of injury.*

The THIRD STAGE of chloroform-narcosis is required—(1) in those cases which it is necessary to produce a very profound insensibility to pain, (2) in those in which perfect muscular relaxation is required.

I think it may be taken as a rule that this stage is not to be induced and maintained unless it is unavoidable. Stertor is the indication of this profound action of chloroform, and if the surgical measures can be proceeded with in the anæsthetic condition short of the stertorous, so much the better. The majority of operations can be so performed; but the following cases demand the profound action:

When operations involve a large extent of sensitive surface, and when they are unusually severe, this stage may be induced. Thus, in the employment of the actual cautery, or severe applications, as strong nitric acid, &c., it is advisable to induce it. Again, it is to be brought about in case of operations upon parts which long preserve their sensibility. The rectum, anus, and parts adjacent, lose their sensibility very late in the course of narcosis. An operation upon them will cause pain when the general cuticular surface is absolutely devoid of sensibility. Hence, as the committee has concluded,† "For most operations

* See letter by the Author, 'Brit. Med. Journal,' March 23rd, 1861.

† 'Abstract.'

about the anus profound anæsthesia is positively demanded." An apparently trifling proceeding, but one which causes the most intense pain, and demands the profound action of chloroform, is evulsion of nails, or any operation requiring much interference with the sensitive structures in which these are imbedded. A part so exquisitely provided with nerves as this is retains its sensibility under symptoms of deep narcosis.

Besides its value as an anæsthetic, the property of chloroform to produce perfect muscular relaxation has proved one of the greatest boons to surgery.

In cases of retention of urine, in which it has been impossible to pass a catheter, after the full effect of chloroform the urine has frequently dribbled away so as to relieve the patient for the time, thus giving the surgeon time and opportunity subsequently to deal with the stricture.

Ether shares in this property in a complete degree, and it is, I think, questionable whether in these cases it is not better to administer it towards the later stage instead of chloroform. The profound stage of narcosis induced by ether seems to be not so dangerous as the profound stage induced by chloroform. I think it would be advisable to give a more extended trial to the plan of inducing narcosis to the commencement of the third stage by means of chloroform, and then inducing and maintaining the state of muscular relaxation by means of ether.

Reduction of dislocations has been facilitated in a most marked manner. "By the employment of these valuable agents," Mr. Erichsen says,* " the muscles of the strongest man may be rendered so perfectly flaccid and powerless in a few minutes as to oppose no action whatever to reduction, which has thus been wonderfully simplified and facilitated. In no department, indeed, of practical surgery has the administration of anæsthetic agents been attended by more advantageous results than in this." It is certain that dislocations of old standing, the treatment of which would have been almost hopeless formerly, are by the agency of anæsthetic agents rendered capable of being reduced. Long-standing fibrous adhesions may be broken down, a proceeding which without anæsthesia both the voluntary resistance and the involuntary tonicity of the muscles would have rendered futile.

* 'Surgery,' 4th ed., p. 287.

Reduction of strangulated hernia has been remarkably facilitated by anæsthetics; and the property of these agents in these cases deserves yet to be more widely known. Anæsthesia, carefully induced to a state of complete relaxation, is more valuable than all the misspent manual efforts at reduction. Mr. Bryant, in a paper read before the Medical Society of London, in March 11th, 1861, has set this proceeding in its true light. In the dangerous condition of strangulated inguinal hernia there should be no delay; chloroform should be administered at once. Mr. Bryant has made an exception in quite recent cases; but even in these I think that the administration of chloroform is better than the warm bath or opium, or both. Dr. Steubel, of Leipzic, independently corroborates the observations of Mr. Bryant, and makes, as I consider it, the most apposite remark, that "chloroform is the least dangerous of all auxiliaries in the reduction of hernia."

The strangulation of inguinal hernia is more influenced by muscular action than that of femoral hernia; the action of anæsthestics, therefore, is in the former case more satisfactory. In both, however, they should be employed, for if, by the relaxation induced, reduction be not accomplished, the state of insensibility is attained for the instant performance of the requisite operation. Operations for the radical cure of hernia require complete relaxation of the muscles. This is necessary, in Wood's operation, before the introduction of the needles.

CHLOROFORM TO CHILDREN.—The irregular and spasmodic breathing of infants and children of tender years renders the use of an apparatus for the administration of chloroform almost futile. The way in which they bear anæsthesia is so favorable, and their immunity from danger is so great, that special means for dilution are scarcely necessary. To infants chloroform may be given by Dr. Inman's plan—merely pouring it upon the palms of the hands and holding them near the mouth and nose. I usually pour the chloroform into the interior of a cylinder of lint and let the child breathe from one extremity of the cylinder.

Harelip.—For the performance of this operation I have given chloroform to an infant a day or two old. The plan I adopt is this. The child is held by a nurse who is seated; its head rests on the knees of the administrator of chloroform, who sits opposite the nurse. The chloroform being applied for a minute or so, and anæsthesia being induced, the administrator resigns his seat to the operator, and when the operation

permits of it covers the nostrils by a thin piece of lint sprinkled with chloroform.

In a similar manner the administration can be conducted when it is desired to remove tumours, to operate upon nævi, to remove deformities—in fact, in case of all operations to children.

CHAPTER XVIII.

CHLOROFORM IN OBSTETRIC PRACTICE.

Of the value of chloroform in this branch of medical practice there cannot be any doubt. Opinions may vary as to the signs which call for its employment, but there can be no disguising the fact that it has proved an immense boon, not only as regards the relief of suffering, but even as regards the prolongation of life.

It has been shown that women are less liable to fatal accidents in the course of the administration of chloroform than are men. Observations show that apparently, in this department, Midwifery, the immunity is special and almost complete.

The Committee of the Royal Medical and Chirurgical Society states that there is no well-authenticated instance of sudden death recorded, either in this country or abroad, as occurring from the administration of anæsthetics during natural labour, when such administration has been conducted by a qualified medical man. It is, moreover, certain that, with due care in its management, chloroform in natural labour is *à priori* very safe, for it is not necessary that any profound action be induced in such cases. Inhalation to the induction of the first stage generally suffices ; the pain is subdued before the consciousness is destroyed.

It may, however, in my opinion, be granted that chloroform has suffered in some degree from its friends. The indiscriminate use of it in every case of labour has been urged by some with more zeal than discretion. There is a middle course, which is safest. To subject the patient who suffers little from the pains of labour to the same treatment as the

one who suffers much is unadvisable. A perennial mother, in whom a few pains complete the process of expulsion, who is so used to the occurrence that she can bear her sufferings with discriminative toleration, will not require anæsthetics. On the other hand, it is impossible to underrate the value of these agents in cases where the pains are violent, where, as in primiparæ frequently, the morbidly acute sensibility aggravates the agony, when the patient gets no respite from the constancy of the pain, where the intense vigour of the contraction threatens danger to the soft parts, or where the mental distress heightens the bodily anguish. These are cases for selection, but when in any branch of practice a universal treatment is asserted Medicine degenerates to Empiricism.

In instrumental labour there can be no doubt that chloroform has tended to the preservation of life. Labours have been thus completed, the patient being in a state of insensibility, when otherwise delivery would have been impossible, and death would have occurred. Such a case happened in my own practice only a short time ago. A lady of uncertain age sent for me; she was evidently suffering from the pains of labour, but she was violent in her indignant denial even of the possibility of it. She became raving, and no amount of force could keep her quiet enough for the necessary manipulations. I am perfectly confident that if chloroform had not permitted extraction by the forceps death would have occurred. These cases are met with by many of us, and in face of them it is impossible to deny the immense value of chloroform. There have probably been one or two cases of death in instrumental labour in which chloroform has had a share. In a discussion at the Obstetrical Society on May 6th, 1863, Dr. Routh related a case of death during delivery by the forceps, chloroform being administered by the nurse. Such an accident has, however, occurred aforetime independently of chloroform. One or two cases are recorded of death a short time after the termination of labour, in which chloroform may, or may not, have contributed to the fatal result. One is recorded by Dr. Pomeroy, of New York; the patient died the day following the delivery. Another is stated by Dr. Faye in 'Schmidt's Jahrbücher.'* In this case, which was one of very difficult labour, the forceps were applied; the patient recovered completely from the nar-

* 'Brit. and For. Med.-Chir. Rev.,' July, 1860.

cotism, and regained consciousness, but died with symptoms of exhaustion, probably more from the violence of the labour than from the effects of the chloroform. The positive evidence of the preservation of life by anæsthesia greatly outweighs these doubtful signs of its danger. These have their value in inculcating caution, and in testifying against indiscriminate administration.

Chloroform in natural labour.—"The current of all experience, since the invaluable discovery of its anæsthetic properties by Dr. Simpson," Dr. Tyler Smith says, "has been to show its general safety and utility." In the majority of cases it is an agent of the highest value. A survey of the objections which have been made to its use will help us in the task of discrimination which certainly has to be undertaken.

Some have objected at the very outset to any agent which abolishes pain. The few who have taken the moral objection that there should be no interference with a process which is intended by Infinite Justice to be accompanied by suffering are answered by the consideration that on this ground there should be no aid, no sympathy, no comfort, afforded to the sufferer. Such a dogma would refuse bread to the hungry, and the cup of cold water to the thirsty soul. This treatment, or rather the withholding of treatment, is antagonistic to the instincts of our common humanity, and is absolutely incompatible with our nature. Pain is hurtful. The shock of the pain of labour has even caused death.* Dr. Simpson's observations go far to prove that in midwifery danger is to pain in a constant ratio. The anguish of the moment of child birth has been occasionally so great, the actual evidence of it has been so prominent, that even the law takes cognizance thereof, and a crime proved to have been committed at such an instant is looked on with a lenient eye. Pain becomes phrenzy. Continued pain begets exhaustion. "We have more than once witnessed cases of labour terminated by the natural powers, and yet which left the patient in such a state from the *nervous shock* that it was doubtful for some time whether she could ever rally; and in one such case death took place apparently from no other cause."† My own experience points to the same conclusion. Called in at the eleventh hour to a protracted case, I have seen death occur from sheer

* Murphy.

† Dr. F. Churchill, 'Brit. and For. Med.-Chir. Rev.,' April, 1855.

exhaustion. "From these dangers," Dr. Churchill says, "we may, in most cases, preserve our patient by a timely and moderate exhibition of chloroform without incurring any risk of injury."

By mitigating pain chloroform diminishes danger (*a*) from shock, (*b*) from exhaustion, and thus tends to the preservation of life. When pain is in excess, or when it is protracted, therefore, chloroform is indicated.

The second objection taken to the anæsthetic is on the ground of its causing protraction of the labour. In reference to this objection, which is allowed to be valid to a limited extent, the following considerations must be entertained:—(1) In animals the uterine contractions persist in the deepest narcosis; contractility remains in the muscular fibre of the womb even after it has ceased in the heart-fibre and in the organs supplied by the ganglionic nervous system. The *direct* action, therefore, of chloroform is not to paralyse the womb. (2) In the majority of cases practical experience shows that the uterine contractions are not enfeebled by chloroform; frequently they are exalted by it. (3) But it may suspend the action of the voluntary muscles which are adjuncts to the expulsive efforts, and (4) it may affect the sympathetic influences. The influence of emotion on the uterine contractions is very marked. Every one knows how even the entrance of the doctor will sometimes put a stop to the pains.

In profound narcosis the uterine contractions, though not stopped, are greatly enfeebled, and the auxiliary muscular powers are suspended. Profound narcosis is not admissible in natural labour.

Several cases have been related in which chloroform has had an undoubted effect in protracting labour. Others have been asserted in which, probably, the anæsthetic had no influence. Thus, Dr. Robert Lee has cited cases in which the forceps had to be employed after inertia of the uterus had followed the administration of chloroform. Whether the inertia in these cases was "propter" as well as "post" is a question; for in all the well-authenticated instances the enfeeblement of the pains has been an obvious effect of the chloroform, and the intensity of them has returned after the withdrawal of the anæsthetic. Dr. Denham has recorded four cases in which suspension of action was proved to be due to chloroform. The number of chloroformed cases whence these were taken was fifty-six; but

it must be recollected that only fifteen were natural labours. It is most probable, therefore, that the suspension occurred generally in the cases in which deep narcosis was induced. Dr. Sinclair* relates a case wherein suspension of uterine contraction took place from the influence of chloroform. It must be noted, however, that the lady had been, by a professional man who had attended her previously, advised to take *plenty of it* without fear. There is no doubt that the case was so protracted as to require instrumental interference solely by the influence of the chloroform ; but it does seem to me probable that the lady had endeavoured to inhale rapidly to the production of too deep a narcosis. The *plenty of chloroform* had, no doubt, aforetime contributed to her frequent floodings. In moderate doses chloroform "occasionally protracts labour by weakening the expulsive powers, but in a large proportion of cases it does not do so."† Frequently the uterine contractions are increased rather than diminished.‡ Dr. Sinclair cites a second case which proves the emotional influence of chloroform. The lady suffered syncope half a minute after commencing the inhalation. This tendency to syncope is a bar to the employment of chloroform. It has been said that this peculiarity exists in a marked manner in diabetic patients (Kidd).

These drawbacks to the use of chloroform are in great measure overcome by careful management. In ordinary labour the first stage of narcotism is sufficient. The smallest proportion of chloroform should be at first administered, and increased till the patient is perfectly tolerant, but then unconsciousness should not be induced. At first let there be mitigation of pain, not abolition ; afterwards complete relief of pain, but not obliteration of consciousness. Patients sometimes cry out for "more," but it is not always advisable to satisfy this craving. Frequently the lady's expression will be after the pain has subsided ; that even whilst her cry was for a stronger dose she was dreamily half-conscious and the suffering was subdued. If even this moderate exhibition of chloroform is seen to stay the uterine contractions, the anæsthetic must be withdrawn, and the case conducted without it.

* 'Dublin Journal,' August, 1864.
† 'Report of Committee.'
‡ Vide Murphy's 'Lectures on Midwifery.'

A third objection has been taken to chloroform, that it disposes to laceration of the perinæum. Dr. Julius, of Richmond, observed to me that in some few cases he thought that, the reflex resistance which exists in a state of complete consciousness being done away with, the perinæum has been by the influence of anæsthesia rendered rather more liable to tear. Dr. Tyler Smith recognises this as an occasional occurrence. Watchfulness, care, and management, do much to prevent it; and it is allowed that the occurrence is very exceptional.

The fourth class of objections is included in the phrase —*It predisposes to complications.* These complications may be immediate (*i. e.* directly following delivery) or remote; the former arising from imperfect contraction of the uterus, the latter from some supposed depressing influence left by the anæsthetic, whereby the tendency to post-partum diseases is exalted.

Just as in a small minority of cases chloroform has been shown to retard the efforts at expulsion, so it does occasionally predispose to hæmorrhage. Observations of the symptoms will usually indicate such cases. In many we find the contractions rather more than less vigorous; in these there can be no danger from imperfect contraction. In the few the influence of the early inhalations in checking the uterine action is sufficient warning that if persisted in it may induce flooding. Itself solves the question.

The remote effects which have been laid to the charge of chloroform may be summed up in the words of one of its opponents:—"It very fruitfully predisposes to puerperal inflammation, chest affections, and to other diseases detrimental to health and life, which aggravates if given in their presence." This wholesale condemnation smacks of the opposition which we have read of to the doctrines of Harvey, of Jenner, of Galileo —"E per se muove." Dr. Simpson's observations, elaborately made and carefully stated, prove to all seeming the converse of the sweeping assertion. The most carefully considered statistics are in the scale against it. The data brought forward by Dr. Sinclair in a recent article in the 'Dublin Journal,* completely disprove it. The Committee of the Medical and

* "Observations on the Administration of Chloroform in Obstetric Practice," by E. B. Sinclair, A.M., M.D., K.D., Vice-President K. & Q.C.P.; 'Dublin Journal,' August, 1864.

Chirurgical Society say—"As a rule, it has no such ill-effects on the nervous or vascular systems of the mother as to retard her convalescence, or render her more liable to any of the forms of puerperal disease. Many physicians believe that it rather favours subsequent convalescence. A small minority hold a contrary opinion."

RULES FOR THE ADMINISTRATION OF CHLOROFORM IN NATURAL LABOUR.—The time to commence the inhalation is determined by the pain. Painful and spasmodic contractions in the first stage may be treated by an occasional inspiration of the diluted vapour. If the os uteri is unyielding chloroform is better than opium and depletion. The usual time to commence the inhalation is the end of the first stage.

If the author's instrument be employed, introduce a drachm of chloroform and commence with the apertures for the admission of air quite patent; after a pain or two let those of the exit tube be half closed. Thus no risk is run of the patient inhaling too strong a dose.

Let her inhale only during the pains; withdraw the chloroform in the intervals.

When the head begins to bear upon the perinæum increase the proportion of chloroform by closing the lateral apertures. If necessary, still further increase it by turning the expiratory valve of the face-piece.

Withdraw the chloroform directly the child is expelled.

It is seldom necessary to repeat it during the expulsion of the placenta.

The following are the rules deduced by the Medical and Chirurgical Committee from answers to questions propounded to various authorities:

"1. Avoid giving it directly after a meal. 2. In primiparæ especially give it very moderately. 3. Dilute well with air, and watch the pulse and the breathing. 4. Keep your finger constantly on the pulse, and the moment it fails discontinue the chloroform. 5. Give it slowly. 6. If depressed, give an occasional stimulant. 7. When the head bears upon the perinæum give it more freely, to promote relaxation. 8. In excitable persons, unless it acts well, it is better not to use it. 9. Always suspend its administration towards the end of labour. 10. Do not continue its use for a prolonged period if not absolutely necessary. 11. When deep anæsthesia is required it is best to have a skilled administrator. 12. With this object

give it slowly, and if it causes delirious excitement withhold it. 13. In ordinary cases administer only as much as will render the patient indifferent to pain rather than unconscious of it, and give a little brandy at intervals."*

The gist of the successful employment of chloroform in natural labour is contained in the words "small doses." I have before said that pain is abolished by the anæsthetic before sensation is obliterated. You can abrogate the heightened sensibility before annulling the normal sensibility. You need not produce unconsciousness. In natural labour it is very advisable to give an extended trial to the anæsthetic mixtures (see Chap. XVI). In this branch of practice one such mixture seems to have proved very efficacious.

I have sufficiently expressed my opinion that the handkerchief should not be used as a vehicle for administering chloroform. I quite approve of the gauze framework introduced by Dr. Skinner for I am sure that this provides a free dilution. I think its objection is that in cases wherein deep narcosis is necessary it scarcely provides sufficient concentration.

CHLOROFORM IN DIFFICULT LABOUR.—"The anæsthetic may be employed with advantage in various obstetrical operations—as forceps, turning, craniotomy, and extraction of retained placenta—unless the patient is much enfeebled by hæmorrhage, when, if given, it ought to be accompanied by the use of stimulants. It may also be employed advantageously to check the paroxysms in puerperal convulsions."†

In cases where the patient being much enfeebled by hæmorrhage turning, or instruments must be employed, the general opinion of those to whom the committee referred is that chloroform is not advisable. This, in my opinion, should only be referred to the case of extreme hæmorrhage. The value of chloroform in operative midwifery is that it renders the patient passive in the hands of the practitioner, favours relaxation of the rigid tissues, lessens the suffering of the patient, and promotes convalescence by reducing the effects of shock and exhaustion.

Turning.—For the operation of turning the chloroform should be administered to the production of the third degree of narcosis. The value of anæsthesia is here most apparent.

* 'Med.-Chir. Trans.,' vol. xlvii, p. 439.
† 'Abstract of Report of Committee.'

Without it the hand can only be introduced into the uterus during intervals from pain; the irritation provoked excites spasmodic contractions, causing great suffering to the patient, and often the operator is unable to bear the tight grasp of the uterus; he is obliged to withdraw the hand, and the reintroduction causes aggravation of the contraction, the spasm, the pain, the bearing-down efforts, and the irritability, local and general. In the other case, the pain being abolished and the contraction overcome by the chloroform, there is no resistance, the operation is performed more quickly, more easily, and probably with less danger.*

Forceps.—Chloroform has, to some extent, taken the place of the forceps. As Dr. Hall Davis has said, it has superseded forcible extraction in cases of nervous agitation and in persistent rigidity of the passages. The blades of the forceps may, in some few occasions, be introduced before the chloroform is applied; but usually, and especially if there is much nervous agitation, or if the attempted introduction causes much pain, the commencement of the second stage of narcotism should be induced previously to the introduction. It is not advisable to induce deep narcotism in forceps cases.

Craniotomy.—The second stage of chloroform-narcotism should be preserved throughout craniotomy.

Hour-glass contraction, Retained placenta.—In these cases the third stage should be induced.

Puerperal convulsions.—These cases, with reference to chloroform, may be divided into three classes:—(1) Those which it cures. (2) Those which it subdues and alleviates, but which require the co-operation of other means. (3) Those in which its use is unadvisable. The fault of not discriminating between these has led to much dispute as to the value of chloroform in such cases at all.

Those instances of puerperal convulsions which are purely reflex, which depend on some local irritation, are completely abolished by the administration of chloroform. So also, are hysteria and hysterico-epileptic convulsions in many cases.

In cases of the apoplectic form chloroform is not contra-indicated; but bloodletting and other adjuncts are required.

* Dr. Skinner, in 'Med. Times,' May 19th, 1860.

Similarly concurrent treatment is required in that numerous class of cases in which the convulsion is due to toxæmia.

The Committee states in the report, "Anæsthetics may be employed advantageously to check the paroxysms in puerperal convulsions; but in the majority of instances their use will not enable the practitioner to dispense with other aids, such as bleeding, the omission of which may be neither prudent nor proper."

In cases wherein the convulsions supervene on an advanced state of disease of the kidney, or wherein there is an undoubted condition of uræmia, the use of chloroform is not advisable.

In the anæmic form of convulsion it is to be used sparingly, and with great caution.

In *puerperal mania* chloroform has proved of immense service. In a paper which attributed ill-effects to chloroform a case is cited, showing that puerperal mania followed its employment. Mania may follow any case of labour. In reply to the objection it is shown, not only that chloroform has diminished the tendency to puerperal mania—a conclusion pointed by the observations of Drs. Simpson, Channing, Beatty, Denham, and others—but in the particular case cited as unfavorable to the use of chloroform it is answered that the anæsthetic "was the agent which subsequently subdued the disease after all others had failed."*

CHLOROFORM IN OBSTETRIC SURGERY.—The value of anæsthesia in permitting ocular examinations under circumstances of pain or over-sensitiveness which would otherwise have forbidden them is undoubted. One observation may here be made. Such a proceeding should never be undertaken—in fact, for any purpose whatever, chloroform should never be given—except a third person be present. Charges have been made which it has been impossible to contradict. It behoves the administrator to take care that there is a trustworthy witness. As has been observed in the 'Lancet,' "It is a scandal to the honorable minds of those who daily administer this great boon to humanity that charges so offensive should ever be made in connection with it."

In *plastic operations* for uterine prolapse, &c., great advance

* Dr. Sinclair, 'Dublin Quarterly Journal,' loc. cit.

has been made by the influence of anæsthesia. The third stage of narcotism is required.*

Ovariotomy.—The practicability of this operation has been greatly increased since the use of anæsthetics.

In giving chloroform for the performance of ovariotomy every care should be taken to prevent vomiting. Mr. Baker Brown recommends that ice should be given the patient to suck *two or three hours before the operation.*

Chloroform should be given to the commencement of the third stage of narcosis. If there are any signs of syncope the inhalation may be prolonged and continued by ether.

In the forty-two cases of ovariotomy narrated by Mr. Baker Brown† chloroform was employed. In two cases it was discontinued. In one of these the pulse fell; the inhalation was stopped, but the patient remained in a half-conscious state during the remaining part of the operation. In the other the patient inhaled chloroform badly, the face and neck became congested, and ether was substituted. In two other cases it was thought better to prolong the anæsthesia by means of ether.

CHLOROFORM IN THREATENED ABORTION.—In such cases, when the hæmorrhage is not excessive, and when there is a reasonable chance of withstanding the tendency to separation of the ovum, chloroform deserves a more extended trial than has yet been allotted to it. In the 'American Journal of Medical Science' for July, 1864, a successful case is recorded. The symptoms were severe pain in the back and abdomen; hæmorrhage had set in; the drugs prescribed had no effect, but when chloroform was administered there was cessation of the hæmorrhage, and the symptoms altogether subsided; yet the lady had miscarried three or four times on previous occasions at about the same period of pregnancy.

Chloroform is very useful in cases of induction of premature labour—its primary, stimulating effect only being attempted. "In *dysmennorrhœa* there is accumulated testimony in favour of chloroform-inhalation."‡

The Chloroform Committee also bears testimony to the value

* In those cases in which rupture of the perinæum has occurred during expulsion, the influence of anæsthesia is very valuable, for the mental distress of the patient who has to submit to the stitches after imagining that the torture is over is usually very great.

† 'On Ovarian Dropsy.' ‡ 'Report of Committee,' loc. cit.

of the anæsthetic in the diagnosis of spurious pregnancy and phantom tumours, in cases of feigned disease, in diagnosis of abdominal or pelvic tumours, and in some hysterical affections.

CHAPTER XIX.

CHLOROFORM IN PRACTICAL MEDICINE.

Chloroform, considered as a therapeutical agent, may be described as a stimulant and narcotic. In the early part of its action, and in cases in which it is given very considerably diluted with air, it is a stimulant, increasing the frequency and force of the heart's action, and, by exciting the sympathetic nerves, causing contraction of the arteries. In the later stage of its action (rapidly if in concentrated doses) it depresses the force of the circulation, causes such a suspension of the influence of the sympathetic nerves distributed to the blood-vessels that the latter become dilated instead of contracted, and induces Narcosis—a state in which there is a paralysis in greater or less degree (1) of the nerves of sensation, (2) of the nerves of motion, (3) of the nerves of organic life.

Its action as a stimulant is simple and uncomplicated, differing in no wise from that of alcohol, ether, or analogous bodies; its action as a narcotic is compound, made up of its paralysing effect in unequal degrees upon the three great divisions of the nervous system.

Used as a stimulant, it is followed by no after-depression; used as a narcotic, its effects may be manifest (1) in an effort of nature at elimination, (2) in the temporary depression which always ensues (in the natural course of things) on any interruption to the course of the functions of life.

Chloroform-vapour can be used in medicine with as much benefit as any of the remedies which are given by the stomach, its dilution being apportioned to the nature of the case requiring it and to the nature of the organism of the patient to whom it is administered.

In the practice of medicine it may be employed either as stimulant or narcotic. As the former, it increases force, subdues spasm, and relieves the slighter forms of pain. As the latter, it

can abrogate pain, abolish all spasm, paralyse muscle, and depress force.

Chloroform in diseases attended with pain.—Neuralgia.—In the treatment of this affection chloroform has proved extremely valuable. The mode of applying it varies with the severity of the case. In slight cases doses so small as to be stimulant only will relieve. A few inspirations will sometimes take away the pain altogether. In such instances chloroform may be applied locally; a piece of lint moistened with liquid chloroform may be laid upon the affected part and covered with a piece of oilskin, or the lint may be dipped in chloric ether, or the Linimentum Chloroformi of the Pharm. Britt. may be applied or rubbed in. A similar treatment is also very useful in pleurodynia.

In cases of more severe neuralgia narcosis must be induced to the first or second stage. After keeping the patient for several minutes under the influence to such a degree that there is complete unconsciousness of pain, the chloroform should be taken away. The pain will after a time probably return, but with diminished severity. A second administration should then be practised, and so on until the suffering is almost entirely abolished or until a natural sleep comes on. This treatment of neuralgia scarcely ever fails. The same is true of sciatica.

In certain cases of neuralgia it is necessary to produce the most profound influence of chloroform—the third stage of narcotism. The fifth nerve taking its rise from a point so close to the origin of the nerves of respiration—so nearly to the vital point—a complete influence is only attained when narcosis begins to compromise breathing. In those cases in which the fifth nerve is affected, and smaller doses fail to relieve the suffering, narcotism should be induced to the production of slight stertor.

The third stage should not, however, be long maintained. In my opinion, it is better to let the patient recover completely, to disembarrass himself of the chloroform, and then repeat the inhalation. In two cases* accidents occurred in the course of inhalation for the relief of neuralgia whereby life was endangered. I believe such would be prevented if complete recovery were allowed before re-exhibition of chloroform. The

* 'Med. Times,' Nov. 6th, 1858, Dr. Skinner; vide 'Report of Med. and Chir. Com.,' Table D.

pain is usually diminished in intensity each time, and after a number of inhalations is subdued altogether.

One fatal case is reported by Dr. Snow as occurring in an early stage of the action of chloroform given for the relief of neuralgia. I believe that we have no better means for relief and cure of neuralgia than chloroform, if the following rules are attended to:

(1) Give the weakest dose of chloroform possible consistently with relief of the pain.

(2) Do not keep up a continuous state of prolonged insensibility, but allow recovery at intervals of a few minutes and reapply the chloroform.

Spasmodic pain, such as occurs in cramp, is relieved by small doses of chloroform; it is of great value in colic and other spasmodic pain in the abdomen, in the pain of calculus in the kidney or ureter, in gastrodynia, and to relieve the intense sufferings of peritonitis.

One instance of spasmodic pain in which the use of chloroform is deserving of special notice is that of the passage of gall-stones. No agent has given such relief as chloroform in this intensely painful affection. Of course, the administration should be under control—should not be conducted by the patient himself. An instance which at once illustrates the violence of the pain of this affection, the insane craving which it excites for any agent that may subdue the pain, and the danger of self-administration, is rendered in the report of the Committee of the Med. and Chir. Society:—A man, aged 40, had suffered from the passage of gall-stones at intervals during six or seven years; he had taken twelve grains of morphia a day, but had reduced the dose to a grain and a half, and inhaled ether or chloroform during the paroxysm. He would use in a few days four or five pints of ether or eight to thirty ounces of chloroform. Subsequently he resorted to laudanum. This state of things resulted in mania but he had lucid intervals. One morning he was found in his bed profoundly anæsthetized by chloroform, but breathing tranquilly. He died; on examination the organs of the body were found to be healthy, but gall-stones were in the gall-bladder, and one of the size of a bullet in the bile-duct.*

CHLOROFORM IN SPASMODIC MUSCULAR AFFECTIONS.—In Chorea chloroform has been tried with good effect. According

* New Sydenham Society's 'Year Book,' 1860, p. 463.

to Dr. Géry, it has been employed at the Hôpital des Enfans Malades in cases wherein the violence of the movements have been beyond the control of opium or belladonna. At first the intensity of the movements is increased, but a perfect calm soon succeeds, and then a sound sleep. The effects have been most beneficial. Dr. Bouchardat relates the case of a girl in whom severe chorea had lasted twenty-one days. She was subjected to the influence of chloroform, at first twice, then three times, then once a day—in all twenty-seven times in fourteen days. At the end of this time she was perfectly cured.* There is no doubt that chloroform, both for remitting the violence of this distressing affection and ultimately inducing a perfect cure, is the best treatment which can be put in force, particularly as all general tonics can be given concurrently.

Dr. Wm. Murray† has narrated a fatal case of chorea in which, though every sedative agent was tried—even grain doses of morphia—no relief was attained until chloroform was administered. A placid sleep ensued on its administration, but the violent choraic movements returned. The administration was then kept up for fourteen or fifteen hours, with but one intermission of half an hour for the purpose of permitting the injection of food. Death ensued from sheer exhaustion forty hours after the chloroform was left off.

Chloroform has been used to relieve *intermittent fever*. Certain Spanish physicians speak very highly of the internal administration of it in this disease. In *tetanus* chloroform induces wonderful relief, but cannot be said to cure. It has been thought that by its power of producing muscular relaxation it might be directly antidotal to the poison of strychnia.

Dr. Anstie's conclusions, derived from experiments upon animals, are—"(1) Chloroform has no direct antidotal action to strychnia; (2) in large doses it may indirectly prolong life by inducing paralysis rather than convulsions; (3) in small stimulant doses chloroform has the power, temporarily, to arrest the convulsions of strychnia, without inflicting damage on the vitality of the nerves; its action in this case is therefore *pro tanto* beneficial."‡ In actual practice chloroform has proved of great value in strychnia-poisoning—not neutralizing the poison, but keeping off suffering, inducing calm, and preventing the

* 'Bulletin Gén. de Thérapeutique,' March, 1855.
† 'Med. Times,' June 4th, 1864.
‡ 'Stimulants and Narcotics,' p. 389.

destruction of tissue dependent on the fearful spasm whilst the poison is being eliminated. A successful case is recorded. A medical man had swallowed a grain of strychnia. The tetanic convulsions were fearful, but were completely subdued by the inhalation of chloroform, of which six ounces were used in less than six hours; there was ultimate recovery.

Enormous doses of chloroform have been consumed in the treatment of tetanus; and though they have failed to cure this almost hopeless affection, they have yet been of great service in abrogating the fearful suffering. "Under the influence of this anæsthetic the pulse falls to its natural standard, the respiration becomes easy, and all indication of suffering subsides; but as soon as the remedy is suspended the fatal symptoms again begin to show themselves."* Another point of value is that under the influence of anæsthesia nutritive enemata may be administered and retained without exciting tetanic paroxysm.

I am disposed, however, to prefer ether to chloroform in all except the early treatment of these cases. Ether produces more muscular relaxation, with less nervous depression. It is to be hoped that another anæsthetic or acinetic will be discovered (Dr. Richardson's researches on the nitrite of amyl may point to it), which in its power over the motor nerve influences shall be a direct antidote to the poison of tetanus.

Infantile convulsions.—Extended experience has shown chloroform to be of much value in the treatment of these affections. Since a case was recorded by Dr. Simpson in which chloroform was used successfully for a child a month old, in whom all ordinary means of treatment had failed,† this form of treatment has been extensively adopted. If administered during the fit, it abates the violence of the muscular movements, calms the spasmodic inspirations, and quiets the whole system. Moreover, it frequently prevents the recurrence of fits.

Chloroform may be administered to children of any age suffering from this affection. It may be poured upon the palms of the hands of the administrator and held near the face, the method proposed by Dr. Inman, or it may be administered upon a cone of lint.

Epilepsy.—In all cases inhalation of chloroform will lessen the severity of the fit, and frequently it tends to prevent recurrence.

* Dr. Tanner.

† 'Edin. Monthly Journal of Med. Science,' January, 1852.

Given at the commencement, it will sometimes postpone the attack. M. Zinnio, in a number of cases of habitual, frequently-recurring epilepsy, caused the patients to inhale three grammes of chloroform twice a day from a handkerchief. In several instances he established an actual cure.

The power of chloroform to reduce the terrible aspect of the paroxysm is undoubted. Its efficacy as a curative agent is, of course, dependent on the nature of the irritation provoking the epileptic convulsion. A very interesting case illustrating the value of the employment of chloroform in the treatment of epilepsy is recorded by Dr. Murray in the 'Medical Times' for June 4th, 1864. A patient, 69 years of age, had very severe epileptic fits, repeated weekly—sometimes still more frequently. He was so much under the influence of the malady that it is stated at the time of the commencement of the chloroform treatment. "Scarcely a day has passed without some symptoms reminding him forcibly of his malady; the chief of these have been dizziness, apathy, wandering, irritability, and incapacity for the slightest exertion. During the thirty years of his disease he declares that he has wandered about the country and had advice from eight dispensaries, ten infirmaries, and many private practitioners, without the slightest relief." The treatment was commenced by the inhalation of about ten drops of chloroform from a linen cloth three times a day. The result was that the fits and all the symptoms of the intervals were completely removed. From a note received by my friend Dr. Thompson, I find that another series of fits occurred after a remission of the treatment; but chloroform being again persevered in for about six weeks, they again subsided, and now four months have elapsed without a bad symptom.

In all such cases one important point is to be borne in mind. We want the stimulant effects of small doses not the depressant effect of narcotic doses. Small quantities and free dilution are therefore the indications.

We have much to do in extending this plan of treatment. Liquid chloroform may be supplied freely diluted with alcohol or ether, and the patient may be allowed to administer it to himself under the surveillance of friends. Danger cannot accrue under these circumstances.

I once administered chloroform to a patient in whom violent epileptiform convulsions occurred consequently upon rupture of an aneurism of the abdominal aorta. The patient was ad-

mitted into King's College Hospital, under Dr. Johnson. During six days of his stay in the hospital the pains from which he had previously suffered were greatly mitigated. At 6 p.m. on the evening of the sixth day after admission, immediately after an evacuation, he appeared to have an epileptic fit. Subsequent to this was delirium so violent that it required three men to hold him. An enema of warm water was first administered, and then I began to administer chloroform. It soon brought about a perfect calm. On awakening from the anæsthetic sleep the convulsive movements were but slight, but there were indications of great pain. I readministered chloroform at intervals of nearly half an hour, and so continued throughout the night until 6 a.m., when the patient, though not in a state of narcotism, was sensibly calmer. Morphia was then administered, both by the stomach and hypodermically. He continued quiet. A slight threatening of a return of the paroxysm occurred in the following day, but it came to nothing. Calm continued until death, which occurred *seven clear days from the commencement of the epileptiform symptoms.*

On post-mortem examination it was found that the aneurism had burst between the layers of the peritoneum in the transverse and ascending mesocolon, as far as the cellular tissue of the pelvis.

There can be no doubt, in this case, that the bursting of the aneurism was gradual, and that it commenced coincidently with the epileptiform symptoms. The evident calm brought about by the chloroform, the subdual of all signs, first of convulsion, secondly of suffering, make me think that chloroform is an agent which is in such a case of the highest value, not only as subduing the pain, but as prolonging life.

It may not be out of place to suggest the use of anæsthetics in course of treatment of intra-thoracic or intra-abdominal aneurisms.

Dr. Murray* relates a case of aneurism of the abdominal aorta which was successfully treated by compression under chloroform. He says, "As an instance of the dependence of a curative process on the influence of chloroform, this case is most striking; for no man, exhausted with pain and weary of life, could have borne for five hours without an anæsthetic such tremendous pressure as was here employed, even though that pressure were to save his life."

* 'Med.-Chir. Trans.,' 1864, p. 187.

CHLOROFORM IN HYSTERIA.—The calmative effect of chloroform may be taken advantage of as well in perversions of sensation as in perversions of motion. We have both in hysteria. In the hysteric paroxysm chloroform has been of great service, but requires to be employed with care. The rapidly succeeding inspirations which patients affected with hysteria frequently make must cause us to pause occasionally in the administration; but hysterical subjects are not unfavorable ones for chloroform unless tendency to syncope is associated with the hysteria. Hysterical pain is frequently removed entirely after anæsthesia by chloroform is once accomplished. Hysterical paralysis is also sometimes removed by its influence. Chloroform may thus be an aid to diagnosis. If in the commencement of the anæsthetic state as well as the recovery from it there is no palpable difference between the amount of muscular action of the two sides, it is evident that paralysis is dependent upon a perversion of voluntary power, and is functional, not organic, in its origin. It becomes us, however, to be very guarded in our use of anæsthesia as a method of diagnosis in feigned disease. Perversion of voluntary power may be as uncontrollable as ocular spectra; the patient must not be accused of feigning a malady without a rigid scrutiny of collateral circumstances.

Hysterical contractions of limbs are especially overcome by chloroform. Anæsthesia being fully induced, the contracted limb should be straightened and a splint applied.*

CHLOROFORM USED TO INDUCE SLEEP.—*In acute mania* it has proved of great service. The discovery of chloroform and the discovery of the treatment by hypodermic injection have been of equal benefit in these cases. Persuasion will sometimes induce the maniac to inhale quietly, but usually he has to be held forcibly until anæsthesia is attained.

In periodic attacks of excitement which affect lunatics chloroform has been of great service. Dr. Snow relates the case of a scientific man who became insane and refused to take food. It was found that if chloroform were given and food were offered during the waking stage, the patient would take it. Chloroform was therefore given before every meal for a long period.

Delirium.—In the delirium of fever small doses of chloroform have acted with very good effect. Thus, in those who

* See p. 145.

have been worn out for want of rest sleep has been induced, and the thread of the perverted condition has been broken. In delirium tremens, however, as I have before argued, I consider chloroform in nowise advisable.

CHLOROFORM IN DISEASES OF THE AIR-PASSAGES.—In irritability of the glottis a very weak atmosphere of chloroform will act as a direct calmative. Strong doses will at once excite a spasm. It is very useful to dull the sensibility of the throat by very weak doses of chloroform prior to making a laryngoscopic examination.

In laryngeal cough, and in spasmodic cough generally, I have used inhalations of chloroform-vapour with good effect.

In *hooping-cough* the influence of chloroform is decidedly to mitigate the paroxysm.

I use it generally diluted with alcohol, and in three modes :— (1) By inhalation of about half a drachm from a cone of lint during the paroxysm. (2) By rubbing into the chest the Linimentum Chloroformi of the 'British Pharmacopœia.' (3) Sprinkling a drachm of chloric ether upon a piece of lint and applying it to the throat and chest. I usually recommend this to be done at bedtime. Though the local action be but trifling, the amount of vapour which is necessarily inhaled by the little patient is sufficient to produce a decided effect, and I have met with much success in this mode of treatment.

In *spasmodic croup* chloroform has proved very useful, but it is necessary to ensure a very free dilution of air at the commencement. The same treatment as that recommended in hooping-cough may be put in force.

I am especially desirous of recommending a trial of the influence of chloroform administered at regular intervals irrespectively of the paroxysm. By the mode recommended, of placing the lint moistened with chloric ether upon the neck, I think this can be very safely accomplished without the presence of the medical practitioner. It may be entrusted to the nurse.

Dr. Hyde Salter, the great authority in *spasmodic asthma*, says, "the inhalation of chloroform is, beyond doubt, one of the most powerful methods of treatment of the asthmatic paroxysm that we possess, as it is also, necessarily, one of the most recent." It has been objected that it is apparently dangerous to administer chloroform to patients suffering from dyspnœa and with signs of semi-suffocation.

The imaginary grounds of this objection are twofold—first, that the vapour is pungent and irritant; secondly, that the nature of the anæsthetic is to cause death by suffocation. Properly diluted, the vapour is not pungent, and, instead of increasing any tendency to spasm, it at once relaxes it. Dr. Salter has never seen any bad effects from chloroform administered in the height of a paroxysm of asthma. The dyspnœa is due to bronchial spasm; the chloroform relaxes the spasm, sets the pulmonary circulation free, and relieves the distress. "The intensity of asthmatic asphyxia, so far from being a reason against the administration of chloroform, is the great reason for its immediate employment."

In every case of asthma chloroform-inhalation relieves the paroxysm. This commencement of relief is afforded by the early inspirations, probably by the direct action of vapour upon the bronchial muscles.

In many cases it not only relieves the paroxysm, but prevents or postpones recurrence, and thus becomes a directly curative agent. For this cause it must be usually administered to the second degree of narcotism. Patients vary in the amount required to produce the postponement of paroxysms. In some, the primary spasm being overcome, the tendency to recurrence is overcome also, and that before consciousness is obliterated. In many cases, however, when the influence of chloroform has passed off the paroxysm returns almost immediately. In these cases the stage of abolition of sensibility must be accomplished. Dr. Salter cites the case of a lady in whom chloroform only gives relief when it sends her into a continuous sleep. Taken at ordinary periods of the day, the relief is but transient; taken at bedtime or at such time as she is likely to sleep continuously, the asthma is sure to cease. This lady never has asthma during sleep.

Patients vary in the benefit which they derive from chloroform. In some, small doses not only relieve the urgent distress, but also prevent recurrence. In others, the recurrence is only prevented by a complete narcosis. In a small minority chloroform does harm by increasing the tendency to recurrence.

In cases of asthma, as in others wherein repetition of the symptoms call for repetition of the treatment, care must be taken lest remote ill-effects follow the habitual use of the remedy. One of the secondary effects of the prolonged use of

chloroform in asthma is an increase of the asthmatic tendency. This must be guarded against by a judicious intermission in the treatment. Other remote effects of baneful character will be presently considered. The use of chloroform must no more be allowed to become a habit than the use of opium.

Spasmodic contractions of the bronchial muscles in very many cases aggravate the intensity of other diseases. In phthisis, in bronchitis, and emphysema, chloroform may be used with great advantage to mitigate the severity of the cough. I have found great value from it in several cases of phthisis. In some cases of chronic bronchitis, in acute bronchitis, and in pneumonia, when danger may occur from stasis of blood in the lungs themselves, it is not advisable to employ chloroform by inhalation.

INFLUENCE OF PROLONGED USE OF CHLOROFORM.—In a case recorded by Dr. Salter these effects have been carefully traced.* Chloroform was habitually used for spasmodic asthma. At the early part of the treatment thirty to fifty drops inhaled from a handkerchief relieved the spasm, induced narcosis, and prevented the paroxysm. The patient was "good for a week." The asthma changed its character after a time. Instead of severe paroxysms with long intervals, the former were milder and more frequent. The chloroform became less operative, it had to be used more frequently, and the dose was required to be increased. In the case of this patient chloroform always induced, many hours after its primary effects had vanished, two symptoms—nausea and a copious flow of viscid saliva from the mouth. After the continuance of the habit of chloroform-taking the following symptoms appeared in order:—(1) Sleeplessness; which was of a most distressing character, and which was only overcome by abstinence from chloroform; (2) Deafness; (3) Apathy and disinclination to society and to conversation; (4) Tremulousness of the hands.

Experience shows that frequent chloroform-inhalation is like dram-drinking. Its effects are very similar to those of alcoholism. It induces first a craving for more. It absorbs the intellectual faculties of the patient and induces inertia. In fact, the narcotism induced by chloroform when oftentimes repeated becomes intoxication; the anæsthetic assumes the character of a baneful luxury. The countenance takes the appearance of

* 'Lancet,' loc. cit.

that of one given to drink. A man* who had been accustomed to the use of enormous doses of chloroform to relieve asthma—frequently forty drachms a day—is reported to have had this appearance on admission to a maison de santé: he seemed in a constant state of dulness; his countenance was peculiar, eyes brilliant and moistened, his features expanded, and he had the look of a person "ravished with delight" or slightly intoxicated.

Patients who have manifested these effects have frequently confessed to having taken enormous quantities of chloroform. One used a pound of chloroform in five or six days. Another 112½ drachms in one day.

In these cases of chronic chloroform intoxication other narcotics may be given without effect. Dr. Salter mentions, speaking of the case in which sleeplessness was brought on by the use of chloroform, that everything in the shape of a sedative was without effect. In another case a patient probably in a state of semi-insensibility met with an accident and broke both legs. Double amputation was performed; morphia would not relieve the after-pain of the operation. At the patient's urgent entreaties chloroform was had recourse to again. He died forty-two hours after the operation, completely exhausted.

Delirium tremens has been produced by this excessive dosing of chloroform. Jaundice has supervened upon its use, and various forms of impairment of nutrition,

These instances are enough to show that the employment of chloroform must not be indiscriminate and must not be excessive.

In all such cases I consider that the patient should not be allowed to have undiluted chloroform. He should be supplied with a mixture of chloroform and alcohol.† Judicious management and a proper alternation with other remedies will remove those clouds which the abuse of chloroform has brought over its name.

* Vide 'Report of Committee of Med. and Chir. Soc.'

† See p. 138.

CHAPTER XX.

CHLOROFORM IN DENTISTRY.

The relations between anæsthesia and dentistry have been very close. At various times narcotics have been used and abused to relieve the pain of toothache or to mitigate the agony of extraction. The drawing of a tooth presents such a perfect exemplum of acute pain that it can scarcely be wondered at that various plans have been suggested from time to time to subdue it. It is certain that out of these plans and suggestions the practice of anæsthesia has grown.

It was from the discovery by Sir Humphry Davy that the inhalation of nitrous oxide gas would relieve the pain of cutting a wisdom tooth that the first notion of inducing anæsthesia by inhaled vapours took its rise. It was for the extraction of a tooth that Horace Wells gave to the notion its first practical embodiment. For a similar operation Morton succeeded in inducing insensibility by means of ether. The first operation performed in this country under the influence of ether was the extraction of a tooth. For tooth-drawing chloric ether was employed by Mr. Jacob Bell.

Since the introduction of chloroform that agent has been employed almost exclusively in this country as an anæsthetic in dental operations. Ether has proved to be long in operation, and not perfectly safe. Nitrous oxide has been used, and it has shown itself to be not free from danger.

A mixture of chloroform and ether (one part of the former to two of the latter) has been used with success. Its adoption is to be recommended largely in the practice of dentistry; for though longer in its operation than chloroform, it is probably safer, inasmuch as the chloroform being diffused among the particles of ether, its vapour is necessarily given off in a more diluted form. Above all things, in these operations everything should be done to lessen any risk.

No doubt chloroform as an anæsthetic has proved of great benefit in cases coming under the care of the dentist, not only as relieving the pain of an operation, but as permitting operations to be performed in cases wherein these would otherwise have been impossible, and thus saving the patient from a pro-

tracted course of suffering, which must have produced an influence upon health and strength, and as allowing prolonged and painful proceedings, which would probably, without it, be stopped short by the urgent entreaty or active resistance of the patient. Not at all unfrequently we meet with patients in whom dyspepsia is caused and prolonged by a bad state of the teeth, a state of things which renders life miserable* and even tends to cut it short. Dr. Snow says, "I have seen at least fifty cases in which the dentist has been able to exert his skill in enabling his patient to masticate only by the aid of chloroform; cases of feeble, aged, or debilitated persons, whose mouths contained between twenty and thirty stumps of teeth or necrosed teeth; and who were able to get rid of them all at two or three operations a few days apart; but without the opportunity of being made insensible would undoubtedly have continued with the mouth in a tender and painful state."

These are facts showing the advantage of anæsthesia in cases of tooth-drawing.

Unfortunately there are facts ranging themselves on the other side. The number of times in which chloroform has proved fatal has been, in the case of dental operations, too notable. Twelve fatal cases have been recorded in the Report of the Committee of the Medical and Chirurgical Society; and these are probably not all. Even taking into consideration the comparative frequency of dental over other operations, it cannot be doubted that chloroform in dentistry has earned a certain amount of opprobrium. How far is this due to carelessness, haste, insufficient dilution, the ready-at-hand method of "choking a patient off"?

Instead of any condemnation of the practice of anæsthesia, it will be well to pass in review the fatal cases. These are extracted from the report of the committee.

* "For there was never yet philosopher
That could endure the toothache patiently."
SHAKESPEARE, *Much Ado about Nothing.*

TABLE OF FATAL CASES FROM THE ADMINISTRATION OF CHLOROFORM IN DENTAL OPERATIONS.

1	Woman, æt. 35	Large quantity used. Patient fully under influence; operation nearly completed	Apparatus used for administration of ether; not allowing free dilution	Symptoms of over-narcotism.
2	Man, æt. 23	Incomplete narcotism; operation not commenced	Ether apparatus	Syncope during early influence.
3	Female	Incomplete narcotism; operation not commenced. Did not readily become insensible; more chloroform applied. One deep inspiration; countenance immediately became pallid; pupils dilated; death	Handkerchief	Sudden over-narcotism from inspiration of insufficiently diluted vapour?
4	Female, æt. 20	Incomplete narcotism frequently induced. Unusual difficulty in bringing on insensibility. Commencing to inhale for the sixth time	Sponge and napkin	Syncope during early influence. Unusual resistance?

5	Female, æt. 36	Complete narcotism. Some teeth had been extracted	Handkerchief	Syncope during complete influence.
6	Female, æt. 32	Incomplete narcotism. Twenty-five drops of chloroform; only a few inspirations; operation not commenced	Sponge and handkerchief	Syncope during earliest influence.
7	Female	Operation completed	Handkerchief. Administered by a druggist	Data insufficient. Fatal result during complete influence.
8	Male, æt. about 35	Operation completed by patient not completely under influence	Handkerchief. Self-administered	Convulsions, ending in death, five minutes after extraction.
9	Male, æt. 29	Operation not commenced. Partially under influence. Symptoms of excitement long-continued	Handkerchief	Syncope during incomplete influence. Unusual resistance?

The other three cases are imperfectly recorded. It is to be understood that though these facts are taken from the Committee's report, the deductions and hypotheses as to the nature of the symptoms are my own.

A consideration of these is quite sufficient to prove that the administration of chloroform in dentistry should be neither indiscriminate nor careless. Before it is attempted the question must be answered, "Do the circumstances of the case call for anæsthesia?" (1) When several teeth have to be removed the question becomes one of a serious surgical operation, capable of causing shock and of inducing exhaustion; the same humanity which would prompt us to dull the pain of amputating a limb would influence us here; we should have no hesitation. Moreover, probably the quietude of anæsthesia would facilitate the necessary proceedings, so as to allow of the performance of the operation in a single sitting.

When only one tooth has to be removed the case is different. The pain is frequently momentary. In such cases, when persuasion avails, and when there are no circumstances *quoad* the patient himself to call for it, I do not advise chloroform.

(2) But there are certain cases of unusual susceptibility to pain in which anæsthesia is absolutely demanded. The previous history of the patient or the behaviour during the preliminary arrangements will usually indicate these. Examples are of no rare occurrence of a state of disease having been induced by the mere extraction of a tooth. Patients will point to it as an era in their lives. "I have never been well since I had that tooth taken out. I have been made more nervous, more fearful of pain," &c. In such cases the use of chloroform is an undoubted benefit.

Anæsthesia having been determined on, certain other considerations come before us.

(1) The condition of a patient about to undergo a dental operation is usually different from that of one about to be subject to a surgical one. In the former case the patient is usually in normal health. This condition is not the most favorable for chloroform.* The resignation evinced by the patient to the dentist is generally very different from that evinced to the surgeon. Whilst the latter is a comparatively calm submis-

* See p. 68.

sion, the other is an active excitement. The influence of emotion is unusually great in the case of the patient of the dentist, and the tendency to faintness is more marked.

The rule should be to calm the agitation of the patient as much as possible.

(*a*) Reassure the patient.

(*b*) Give a glass of wine, or a little brandy and water.

(*c*) Let the patient be quiet for some minutes in the position in which he is to inhale.

(*d*) Let this position be not bolt upright, but partially, at least, recumbent.

(*e*) Let there be no hurry nor fuss. Let it be remembered that the weak are frequently better patients than the strong in their submission to the influence of chloroform.

(*f*) The patient should be cautioned to abstain from food for three or four hours previously to the inhalation ; the meals of the day on which the inhalation is to occur should be very light.

(2) As to the administrator and the ethics of the administration. Chloroform, like hydrocyanic acid, should never be trusted in incompetent hands. A non-qualified person dosing a patient with hydrocyanic acid and causing death would run a very immediate risk of a verdict of manslaughter. In all dental cases it is better that one experienced in conducting the inhalation of chloroform should administer it. The operator should never be the administrator *in any case in which abolition of consciousness is necessary.* Certain cases in which only the first stage of narcotism is induced, in which the patient preserves consciousness, are thus excepted. In any case it should not be administered to the slightest degree without the presence of a third person. It is desirable to avoid the possibility of scandals and libels.

(3) The commencement of the inhalation. In dentistry I consider it especially necessary to give chloroform very gradually. The same reasons which indicate reassurance and gentle treatment indicate the gradual administration of chloroform.

What is the great element of danger? Syncope—syncope which may occur in any case without chloroform, but which the action of chloroform renders of more serious import. In five out of the nine cases noticed in the previous page the arrest of life was during the early influence of the chloroform.

In no case more than for the performance of dental operations does practical experience show that the symptoms of anæsthesia are induced calmly, quietly, and safely, when chloroform is given in such manner that the system shall gradually become tolerant of it.

(4) Mode of administration. I have little to add to the opinions I have before expressed on this subject, and I have no reason to modify them.

It is to be noticed—be the fact smoothed over, theorised over, as it may—that in all these cases in which chloroform has been fatal in dental operations means has been adopted which afford no certain safeguard against the injurious influence of a too-concentrated atmosphere. In the first and second case an ether apparatus was used; proper enough for that anæsthetic, but dangerous to use for chloroform. In all the rest the ever-ready handkerchief or napkin was employed.

I can only record my opinion that in all cases of chloroform-administration for dental operations either Mr. Clover's method or that recommended by me should be put in force.

In the first place, let the patient be gradually accustomed to the vapour, and, in the second, provide a safeguard that the latter shall never be presented in too concentrated a form.

I may mention that whenever anæsthesia is thus induced I never meet with the struggling and the muscular movements which I have seen to be such a nuisance under other circumstances.

(5) In no case should anæsthesia be induced to a deeper degree than the circumstances of the case require.

In very many instances where only one tooth has to be removed the first stage suffices. The tooth may be extracted before consciousness is obliterated. Thus, Mr. Coleman tells how he extracted his own tooth without any pain whilst partially under the influence of chloroform.* Patients have been able to express themselves ready for the performance of the operation, feeling no pain, yet knowing all that is going on. Thus, Mr. R. Bealy Lubbock† relates how that he agreed with the operator on a signal whereby he should express himself ready for the extraction of his tooth while he was yet inhaling. He held a handkerchief in his hand, which he dropped when

* 'Anæsthesia in Dental Operations.' Lecture.

† 'Brit. Med. Jour.,' March 8th, 1862.

he considered sensation abolished. The dentist removed the tooth immediately, and no pain was felt. It must be remembered that some apparent expressions of pain may escape the patient, and yet he will subsequently assure us that he has experienced scarcely any disagreeable sensation.*

In cases wherein several teeth have to be removed the second stage is required.

Before consciousness is lost the patient should be requested to keep the mouth open. The spasmodic rigidity of the jaws is often a difficulty in the performance of dental operations under chloroform. I have before said that it is *never* desirable that chloroform should be given to such degree that the muscles of the jaw be relaxed. If, therefore, the administration be not continued with the mouth sufficiently open, it requires that the jaws be moved apart by force. The simple request to the patient to retain the mouth open is frequently sufficient, for then a little forcible depression of the lower jaw will easily widen the gap. Sometimes, however, the teeth are firmly clenched, and then a lever of hard wood should be introduced, and slowly and forcibly the jaws opened. At the same time one hand should depress the chin. Various instruments have been contrived for this purpose. One was used by Dr. Snow.† Another has been devised by Mr. Coleman.‡

(6) Resistance to chloroform.—Seeing that in certain cases —especially in those of hard drinkers and of robust men— there is an unusual resistance to the influence of chloroform; seeing, moreover, that in cases wherein the symptoms of resistance and of excitement have been manifest there has frequently been a fatal result, I consider that we should be taught to forego the administration in some instances in obedience to certain signs. In cases wherein a large quantity of chloroform is inhaled with no effect in inducing anæsthesia, when in the course of its gradual administration violent and prolonged excitement occurs, I counsel that it be removed altogether, and the operation be postponed, or accomplished without its influence.

(7) Repetition of chloroform during the operation.—When several teeth have to be extracted this generally becomes an imperative necessity. The patient during the progress of the

* See p. 30.

† Made by Matthews, of Portugal Street.

‡ 'Med. Times and Gaz.,' January 26th, 1861.

operation breathes air, necessarily, both by nostrils and mouth. It is difficult to approach any chloroform to the patient without interfering with the operator. The operation, therefore, must be interrupted while chloroform is again applied, or else some means must be adopted to keep up the anæsthesia with the least possible discomfort to the operator. The usual plan used to be to hold a bit of lint or cotton wool moistened with chloroform near the nostrils. This method I have often seen fail. The patient would wake up, and there would be evident expressions of pain. In some cases, especially in those of operation for removal of the jaw, this tendency to awaken imparted a great horror to the proceedings. I myself felt the want of some means for keeping up anæsthesia in such cases, and I thought that the plan of M. Faure, who administered chloroform by the nostrils, might be made applicable. M. Faure advocated this plan for the *production* of narcotism, believing that if chloroform-vapour were inhaled by one nostril, the other being patent to the air, all danger, whether from insufficient dilution or otherwise, would be overcome. Practical experience has, however, shown that there is difficulty in employing it for the induction of anæsthesia, because of the length of time which the process requires, the impossibility in some cases of inducing insensibility, and the variation of susceptibility in different patients. It is very different, however, when the object is not *production* of anæsthesia, but *maintenance* of it. For such a purpose I have found a modification of the plan answer admirably. I believe a somewhat similar proceeding was first put in force by Dr. Richardson, in a case where Mr. Spencer Wells removed half the lower jaw. My own modification served its purpose perfectly. In the 'Medical Times' for May 25th, 1861, is a report of a case of excision of the superior maxilla by Mr. Fergusson, in which I administered the chloroform. Nearly the whole of the upper jaw was removed, together with part of the soft palate. The reporter states—"In the above case the patient was kept fully under the influence of chloroform by Dr. Sansom, by means of chloroform inhaled by the nostril." The process of administration is thus described:—"A glass reservoir, capacity two ounces, is connected at its upper part with two tubes, one of glass, very short, of nearly half an inch in diameter, and terminating in a funnel-shaped extremity open to the air; the other a flexible tube, of one quarter of an inch in diameter

and about eighteen inches in length, with an extremity adapted to the patient's nostril. The patient is first brought under the influence of chloroform in the usual way. When the operator commences the manipulation upon the mouth a drachm of chloroform is poured into the glass reservoir through the funnel-shaped extremity of the glass tube; the reservoir is then shaken so as to project the chloroform against the sides, and thus favour the evaporation. The flexible tube is then pushed up one of the nostrils of the patient, so far as it will penetrate, with gentle force. The patient now breathes by one nostril air impregnated with chloroform-vapour (by its passing over the evaporating surface of the reservoir), and by the other nostril and by the mouth, pure atmospheric air. The free nostril is used as a valve, to be closed or left open, according as the patient requires more or less of the anæsthetic. The mouth remaining open, there is quite sufficient dilution with air ensured, although the free nostril be completely closed. The flexible tube admits of the apparatus being moved anywhere out of the operator's way. In the present instance the patient was kept well under the influence of chloroform, the administration not interfering at all with the operation."

Experience has shown that in these cases certain precautions must be taken. In the first place, it must be recollected that all patients have not the faculty of breathing through the nostrils. I received a painful illustration of this fact. Mr. Henry Lee was about to operate upon a boy for a tumour of the jaw. I endeavoured to complete the narcotism by introducing the elastic tube into the nostril in the manner described. Fortunately the operation had not commenced. On Mr. Lee attempting it the boy cried out. He said, "Sir, I can't breathe through my nostrils; I never could." Of course, such cases are few and far between.

But, again, we nearly always find that one nostril is more pervious than the other.

On the other hand, the advantages of nasal inspiration are considerable. The vapour is thus spread over a large extent of absorbing mucous membrane; a less quantity manifests a greater effect than in the case of oral respiration.*

Mr. Coleman† has invented an instrument for giving chloro-

* See Dr. Pidduck, 'Brit. Jour. of Dental Science,' Feb., 1864.

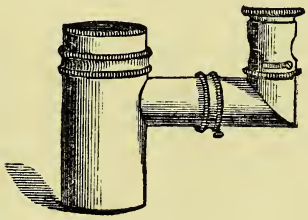
† 'Lancet,' Jan. 11th, 1862.

form by the nostrils. In this the flexible tube carrying the vapour ends in an arrangement for applying it to *both* nostrils. This I consider to be a doubtful benefit. It is so much better, in my opinion, to use the free nostril as a valve for the admission or exclusion of air. Mr. Coleman has adapted to his instrument an india-rubber ball, which, on being squeezed, forces a stream of air over the chloroform, and thus facilitates the evaporation. This is only used in cases in which it is necessary to increase the proportion of chloroform to deepen the narcotism.

I have quoted these details under the head of "Chloroform on Dentistry" because I have found it to be of such great value in any case wherein more than one tooth has to be removed.

I have now adapted a nostril-tube to my own inhaler. The mode of conducting the inhalation is as follows:

FIG. 15.



The Inhaler, the mouthpiece removed. (The apertures in the upright tube should be closed.)

FIG. 16.



The flexible tube to be applied to the Inhaler, &c.

(1) The administrator requests the patient to press each nostril successively, and breathe through the other; he thus ascertains which is the more pervious, and in this, when the time comes, he inserts the nostril-tube.

(2) He adapts the ordinary mouthpiece to the inhaler, keeping the nostril-tube (fig. 16) in his pocket; he induces narcotism in the usual manner.

(3) When the operation is just to be commenced he detaches

the mouthpiece, and taking the nostril tube from his pocket fits it upon the inhaler and inserts the extremity into the nostril.

(4) He can then stand behind the patient, holding the inhaler with one hand, and having the other free, to close the other nostril if necessary.

If it be required to administer a still stronger vapour, air may be blown over the chloroform by means of a small, hollow, india-rubber ball. I find this is seldom needful.

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